Institution: University of Cambridge
Unit of Assessment: 1 – Clinical Medicine
1. Unit context and structure, research and impact strategy

1.1. MISSION

The mission of UOA1 is to reduce human morbidity and mortality through research that uncovers the basis of health and disease, discovers novel diagnostic and treatment strategies, and deploys these insights to transform medical practice.

1.2. ORGANISATIONAL STRUCTURE

To achieve our mission, 340 of our 382 category A staff (363.43 FTE) are grouped within five **Strategic Research Clusters** (SRCs; total active grant funding GBP643 million) focussed on leading causes of death and disease across all age groups (Figure 1):

- ***Cancer*** causes 165,000 deaths/year in the UK and the highest economic loss by disease worldwide. It is the focus of 120 staff supported by a total research grant portfolio of GBP300.5 million.

- ***Cardiovascular and Respiratory*** diseases including ischaemic heart and chronic lower respiratory tract disease are among the top five causes of death worldwide. They are the focus of 35 staff supported by a total grant portfolio of GBP59.2 million.

- ***Infection and Immunity*** research on immunity, pandemics, pathogen control, antimicrobial resistance and autoimmune and inflammatory disorders is the focus of 103 staff supported by a total grant portfolio of GBP152.2 million.

- ***Metabolism and Endocrinology*** research is the focus of 60 staff supported by a total grant portfolio of GBP91.3 million who study a variety of diseases including diabetes that causes of >1.5 million deaths/year in the UK.

- ***Women and Children's Health*** reported as 'Reproductive Biology' in REF2014, has expanded in scope to engage 22 staff developing approaches to predict, detect and treat precisely, diseases in women, neonates and children. They are supported by a total grant portfolio of GBP39.8 million.

SRCs transcend the University of Cambridge organisational structure, uniting staff with common interests and complementary expertise (Figure 1). They also align with our National Institute for Health Research Biomedical Research Centre (NIHR-BRC) themes.

Since REF2014, we have established five **Cross-Cutting Themes** (CCTs; total active grant funding GBP53.2 million) led by 41 or our Category A staff, to provide our SRCs with expertise and technologies in commonly used disciplines (Figure 1). SRCs in '*Genomics and Cell Biology*' and *'Stem Cell Biology'* reported in REF2014 have evolved into CCTs, reflecting the broad application of these disciplines. Details of CCT infrastructure and associated networks are provided in Sections 1.3 and 3.3. In summary:

- ***Clinical trials:*** Led by our NIHR Clinical Trials and MRC Biostatistics Units, supports the design and conduct of local, national and international early and late phase clinical trials. Since

REF2014, UOA1 conducted 3,352 clinical interventional and observational studies to which 144,030 patients were recruited.

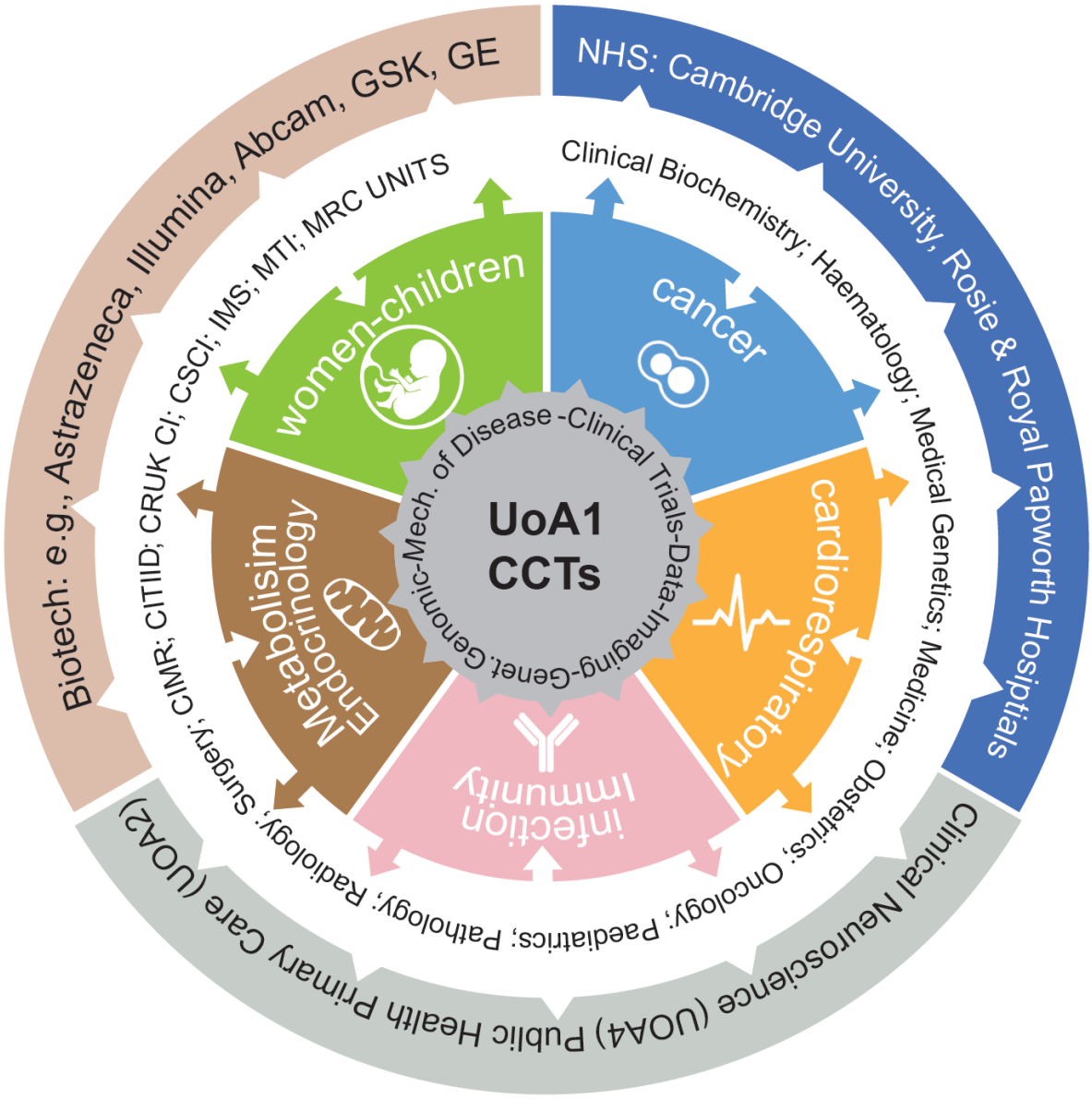

Figure 1, Structure of UOA1: Central grey circle shows our five Cross Cutting Themes (CTTs) that support our five Strategic Research Clusters (SRCs coloured wedges). SRCs and CTTs are drawn from University Departments, Institutes and Units (outer white circle). UOA1 collaborates with UOA2 and UOA4, major industry partners and with NHS organisations to deliver impact (outer circle)

- ***Data Science (in association with UOA2):*** Uniting the National Turing Institute, the Centre for Mathematics in Healthcare, and our newly established Cambridge Centre for Artificial Intelligence (AI) in Medicine supported by GlaxoSmithKline and AstraZeneca. This CCT applies advanced computation, AI and machine learning to enable basic discovery and translational research.

- ***Genetics and Genomics:*** This coordinated network of facilities supports all aspects of genetic and genomic analysis enabling basic discovery and translational research: the Cancer Research UK (CRUK) Cambridge Institute sequencing facility; Department of Medical Genetics

sequencing facility; CRUK-AstraZeneca Functional Genomics Facility; East Midlands and East of England Genomic Laboratory Hub (one of seven NHS Genomic Hubs delivering the national NHS Genomic Medicine Service to improve healthcare outcomes through the integration of genomic technology into routine patient care; accredited to ISO 15189:2012 standard); the Department of Clinical Genetics; and the nationally accessible, Cambridge-led, NIHR BioResource of >150,000 healthy volunteers and patients with common and rare diseases with whole genome sequences of >13,000 rare disease patients.

- ***Imaging science (in association with UOA4):*** this Department of Radiology and Wolfson Brain Imaging Centre led CCT provides expertise and infrastructure in: (i) 7T MRI, Advanced Functional MRI, Hyperpolarised MRI, PET/MR, and pre-clinical imaging; (ii) Radiochemistry, radiopharmacy, and ^{13}C-MRI pharmacy; (iii) Medical physics infrastructure; (iv) Radiomics and radiogenomics; (v) AI and Deep learning approaches integrating imaging data with other clinical tools.

- ***Mechanisms of Disease (in association with UOA5):*** This coordinated network of facilities provides expertise in cell biology (Cambridge Institute of Medical Research, Cambridge Institute of Therapeutic Immunology and Infectious Disease), tissue regeneration (Wellcome-MRC Cambridge Stem Cell Institute), cellular imaging (Wellcome-MRC Cambridge Stem Cell Institute; Cambridge Institute of Medical Research), structural biology (Cambridge Institute of Medical Research) and *in vivo* research (Anne McLaren Building).

1.3. CO-LOCATION ON THE CAMBRIDGE BIOMEDICAL CAMPUS

Members of our SRCs and CCTs are drawn from 19 organisational units within the University (Box 1.1). Many are widely recognised as international thought leaders across a broad range of basic, applied and clinical research disciplines. To accelerate the impact of their research, our members are co-located within a vibrant community of 20,000 researchers, industry scientists and clinicians on the 140-acre Cambridge Biomedical Campus. This close proximity provides an environment which fosters the interdisciplinarity and creativity critical for transformational discovery science, fuelling advances in healthcare. The Biomedical Campus is one of six Life Science Opportunity Zones in the UK and one of eight national Academic Health Science Centres designated by NIHR and NHS England/Improvement. It is a joint venture between the Schools of Clinical Medicine (UOA1,2,4) and Biological Sciences (UOA5) and our NHS and industrial partners.

- **NHS partners (see also Section 3.3.2):** Cambridge University Hospital NHS Foundation Trust and embedded Cambridge Clinical Research Centre; the East Midlands and East of England Genomics Laboratory Hub; NHS Blood and Transplant's Donor Centre and research facilities; and the new Royal Papworth Hospital–treating >100,000 cardiothoracic hospital and transplant patients each year (opened 2019). With our NHS partners we host the Cambridge NIHR-BRC, renewed in 2017 as the largest single BRC grant in England (GBP114 million/5 years).

- **Industry partners (see also Section 3.3.4):** AstraZeneca's new Research and Development Global Headquarters (completed, opening 2021) on 11 acres adjacent to Cambridge University Hospital and Royal Papworth Hospital. It will ultimately house >2,000 scientists, becoming the company's largest centre for oncology research, as well as cardiovascular, metabolic, respiratory, inflammatory and autoimmune disease research, thereby aligning directly with our UOA1 SRCs. Other new industry partners who have established research facilities on the Biomedical Campus since REF2014 include Abcam, Illumina, and Inivata.

- **Campus and Regional Academic Partners:** The world-renowned MRC Laboratory of Molecular Biology (LMB) on the Biomedical Campus opened its new building in 2013 and

houses 440 scientists, including dedicated space for the University which houses members of UOA1. For example, Lalita Ramakrishnan (Box 1.2) was recruited to lead the University of Cambridge Molecular Immunity Unit, which is physically integrated within the LMB, but is also part of the Department of Medicine and the Cambridge Institute of Therapeutic Immunology and Infectious Disease, and houses 60 scientists (Section 3.3.2). Furthermore, the Babraham, Wellcome Sanger and EMBL-European Bioinformatics Institutes all lie within six miles of the Biomedical Campus providing world-class collaborations that enrich further the UOA1 research environment (Section 3.3.4).

BOX 1.1: UOA1 Constituent elements:

10 speciality Departments: Clinical Biochemistry, Haematology, Medical Genetics, Medicine, Obstetrics and Gynaecology, Oncology, Paediatrics, Pathology, Radiology, and Surgery.

Six physical Institutes: Cambridge Institute for Medical Research, Cancer Research UK (CRUK) Cambridge Institute, Wellcome Trust-MRC Institute of Metabolic Sciences, and new since REF2014, the Cambridge Institute of Therapeutic Immunology and Infectious Disease, Milner Therapeutics Institute and Wellcome-MRC Cambridge Stem Cell Institute housed in the Jeffrey Cheah Biomedical Centre. The Cambridge Heart and Lung Research Institute will open December 2021.

Three MRC Units in Cancer, Metabolic Diseases, and Mitochondrial Biology.

1.4. RESEARCH AND IMPACT STRATEGY

1.4.1. Research and Impact Objectives

To achieve our mission (Section 1.1) UOA1 pursues five overarching **Research and Impact Objectives** that span the breadth of biomedical research, from fundamental discoveries in normal and diseased tissues to the development of novel diagnostic, prevention and therapeutic strategies:

1. ***Advance understanding of health and disease*** through the highest quality basic research. Our longstanding strengths in fundamental biology enables deep and broad study of normal biology and how it goes wrong in disease.

2. ***Diagnose disease early*** by discovering and developing new diagnostic approaches that guide clinical decision making so that patients can access tailored treatment with the best opportunity for a positive health outcome.

3. ***Practise precision medicine*** through research designed to determine the optimal intensity of treatment for individual patients, balanced with the prediction of disease aggression.

4. ***Develop effective new therapies and intervention strategies*** for rare and common diseases.

5. ***Devise effective multidisciplinary care pathways of chronic diseases*** through coordinated, evidence-based, multidisciplinary research; thereby extending the length and quality of life of patients with chronic disease.

1.4.2. Strategic Pillars

Four **Strategic Pillars** strengthen and support the pursuit of our Research and Impact Strategic Objectives:

1. ***We unite our diverse and complementary skills around a common, over-arching mission***, enabling aligned and purposeful growth of our environment (Section 1.1).

2. ***We deploy collective leadership to ensure our Research and Impact Strategy is flexible and responsive to healthcare challenges and that we recruit and develop a world-class, diverse research community***. The Council of the School of Clinical Medicine and the Faculty Board–the two principal governance vehicles of the School–are chaired by Prof. Patrick Maxwell (Regius Professor of Physic) and include the Head of School of Biological Sciences (Philpott) as well as the leaders of: each SRC and CCT; Equality, Diversity and Inclusion panels (Section 2.9); Training and Mentoring bodies (Section 2); Open Research and Integrity officers (Sections 1.5 and 1.6); and the Chairs of UOA2 (Danesh) and UOA4 (Chinnery).

3. ***We invest in our people, culture and infrastructure*** to maintain the vitality and sustainability of our research environment that promotes equality, diversity, openness and integrity; thereby encouraging the recruitment, development and retention of a high-quality workforce.

4. ***We specifically promote multidisciplinary networks across and beyond UOA1 to maximise the depth and reach of our impact.*** This pillar is underpinned by the co-location of our staff on the Biomedical Campus together with our NHS and industrial partners.

1.5. STRATEGY-DRIVEN PROGRESS DURING THE ASSESSMENT PERIOD

1.5.1. We recruited and retained a high-quality workforce (see also Section 2)

Since REF2014, UOA1 has recruited 90 new staff (22 at the rank of Professor) and promoted 71 staff (including 37 Professors, 11 Principal Research Associates, 5 Senior Lecturers and 18 Readers). These individuals have contributed directly to the evolution and impact of our research environment (Box 1.2).

1.5.2. We delivered impact through multidisciplinary networks (Figure 2; see also Sections 3.2.1 and 4.1)

Ten networks aligned directly with our research objectives were established, or significantly expanded, since REF2014 supported by >GBP120 million in grant funding:

- **Networks advancing understanding of health and disease:**
  - ***Cambridge Cardiovascular Network*** **(established 2014 became a University Interdisciplinary Research Centre in 2019)** >500 researchers from UOA1,2,5,6,9 and 12, our NHS partners, major pharmaceutical and biotechnology companies. Oversees strategic international collaborations e.g. Harvard University and the National University of Singapore. Develops new diagnostics and treatments of cardiovascular disease, **generating REF2021 Impact Case Study Morrell et al.**
  - ***COVID-19 Genomics UK Consortium (COG-UK)*** established 2020 with GBP 20 million by Peacock (Box 1.2, Executive Director of COG-UK), has led sequencing of >160,000 SARS-CoV-2 genomes made available globally in open access databases, positioning the UK as the world-leader in COVID-19 sequencing, guiding government decisions on disease control and vaccine roll-out, **generating Impact Case Peacock et al.**
  - ***Cambridge Infectious Diseases Research Centre*** **(became a University Interdisciplinary Research Centre in 2016)** ***and Immunology Strategic Research Network*** >100 principal investigators across all six University schools, the Wellcome Sanger and Babraham Institutes and industry (e.g. AstraZeneca and GlaxoSmithKline), to develop solutions for intractable infectious diseases **generating REF2021 Impact Case Studies Goodfellow et al., and Peacock et al.**

- ***Cambridge-Africa*** promotes mutually beneficial research between UOA1 researchers and 50 African Institutions across 18 countries with regional hubs in Ghana and Uganda. Supports research to prevent epidemics and pandemics involving >40 African PhD fellows in Africa and Cambridge and 75 Africa-based postdoctoral fellows.

BOX 1.2: Examples of UOA1 recruits who have directly shaped the research environment since REF2014:

2014 - Prof. Lalita Ramakrishnan recruited from the University of Washington, US: elected Member of the US National Academy of Sciences (2015) and Fellow of the Royal Society (2018). Leads efforts to understand the pathogenesis of bacterial infection.

2015 - Prof. Richard Gilbertson recruited from St. Jude Children's Research Hospital, US: elected FMedSci (2017). Led the renewal of our CRUK Major Centre (GBP35 million) and was instrumental in securing government funding for a new Cambridge Cancer Research Hospital on the Biomedical Campus (2020; Section 1.4.1).

2015 - Prof. David Rowitch recruited from UCSF, US: elected FMedSci (2018). Instrumental in securing government funding (GBP100 million) for a new Children's Hospital on the Biomedical Campus (2019; Section 1.4.1).

2017 - Prof. Evis Sala recruited from Memorial Sloane Kettering Cancer Centre, US: received the British Institute of Radiology/Canon Mayneord Memorial Award (2020) and has pioneered radiomic imaging and AI on campus.

2019 - Prof. Sharon Peacock recruited from University College London: Executive Director and Chair of the COVID-19 Genomics UK Consortium (COG-UK) and Public Health England Director of Science (Pathogen Genomics). Leads national research into COVID-19 genomics and directly informs our COVID-response strategy.

- **Networks enabling early diagnosis:**
  - ***INNODIA* (established 2016; EUR57.7 million),** Innovative Medicines Initiative 2 network of 31 academic institutions, six industrial partners, two patient organisations and one SME developing strategies to detect and prevent Type 1 diabetes. All clinical trials co-ordinated by Cambridge UOA1.
  - ***CRUK International Alliance for Cancer Early Detection and Krishnan-Ang Foundation* (both established 2019; GBP13 million)** >200 clinicians, biologists, epidemiologists, mathematicians, engineers, chemists, and physicists across UOA1,2,5,8-12 and the University of Manchester, University College London, Stanford University and Oregon Health & Science University, US; inventing and deploying early cancer detection devices, hosting authors of **REF2021 Impact Case Study Fitzgerald et al.**
  - ***Next Generation Children's Project* (established 2016; grant GBP2 million)** collaboration with the NHS and NIHR for rapid whole genome sequencing of sick children in neonatal and paediatric intensive care units. Highlighted by Professor Dame Hill, Chief Scientific Officer NHS England as demonstrating '*benefits of whole genome sequencing to significantly improve care for seriously ill children….as part of a mainstream NHS service*'.
  - ***INTREPID (Integrative Translational Research in Primary Immunodeficiency) consortium* (established 2020; grant GBP 4 million)** Cambridge-led collaboration with Genomics England and the NIHR Bioresource, uniting 29 UK clinical immunology centres, scientists, mathematicians and patient groups to develop whole-genome sequencing for early diagnosis of adult-onset immune deficiency.

- **Networks practising precision medicine:**
  - ***Mark Foundation Institute for Integrated Cancer Medicine and aligned AstraZeneca award* (established 2017 grant of GBP13 million)** >80 UOA1 staff, population scientists, mathematicians, computational scientists and physicists (UOA2,9-11) and industry partners inventing and applying AI approaches to precision cancer medicine hosting authors of **REF2021 Impact Cases Study Caldas et al., and Coles and Earl et al.**
  - ***Cambridge Centre for AI in Medicine* (established 2020 with support from GlaxoSmithKline and AstraZeneca GBP7 million)** pioneering AI and machine learning technologies to transform science, medicine and healthcare through biological and physical science discovery research.

- **Networks developing new treatments:**
  - ***Cambridge Academy of Therapeutic Sciences* (CATS; established 2017)** educates researchers through MPhils in Therapeutic Science; promotes academic-industry collaboration by hosting 'Industry Experts in Residence'; and connects academics with public policy professionals to promote medicine safety.

- **Networks advancing multidisciplinary care of chronic diseases:**
  - ***Versus Arthritis Tissue Engineering and Regenerative Therapy Centre* (2011, renewed 2016 GBP1.9 million)** unites UOA1 with researchers at the Universities of Aberdeen, Birmingham, Newcastle and York as well as Robert Jones and Agnes Hunt Orthopaedic Hospital to develop new treatments for osteoarthritis. Related programmes include: Cambridge-led, UK Regenerative Medicine Platform (UKRMP) Smartstep research consortia (award 2014, GBP1.1 million) and Edinburgh-led UKRMP Engineered Cell Environment Hub (award 2018, GBP5.1 million).
  - ***NIHR Blood and Transplant Research Unit in Organ Donation and Transplantation* (established in 2015 grant GBP5.3 million)** in collaboration with Newcastle University conducting research to increase the number of suitable organs for donation and transplant survival, hosting authors of **REF2021 Impact Case Study Nicholson et al.**

1.5.3. We delivered impact through basic discovery and translational science (Figure 2)

In addition to large-scale, Network-driven research, UOA1 Principal Investigators in each of our SRCs advanced our mission through research addressing each of our Strategic Objectives:

- ***We advanced understanding of health and disease:***
  - ***Cell biology and homeostasis*: *Infection and Immunity*** deciphered how tissue-immune cell cross talk protects the brain (Fitzpatrick et al., *Nature* 2020) and kidney (Stewart et al., *Science* 2019) from pathogens; discovered a highly conserved multi-functional purine nucleoside enzyme (FAMIN), the loss of which causes monogenic Still's and Crohn's disease, thereby changing fundamentally understanding of purine metabolism and unmasking a new treatment strategy of autoimmune disease (Zaeem-Cader et al., *Cell* 2020); provided a platform for understanding pathological mechanisms and treatment strategies of immune-mediated disease (Bashford-Rogers et al., *Nature* 2019). And identified mechanisms by which rare human genetic variants protect against severe malaria (Kariuki *et al., Nature* 2020). And determined the impact of novel macrophage migration and survival mechanisms on the pathogenesis of mycobacterial infection (Berg et al. *Cell* 2016, Madigan et al. *Cell* 2017, Roca et al. *Cell* 2019). ***Metabolism and Endocrinology*** uncovered the molecular mechanisms of: mitochondrial ADP/ATP carrier transport (Ruprecht et al., *Cell* 2019); AP2 Clathrin-mediated endocytosis (Kelly et al., *Science* 2014); and identified SEMA3 signalling as central to hypothalamic melanocortin circuits, regulating energy homeostasis to prevent severe obesity (van der Klaauw et al., *Cell* 2019). ***Cancer*** mapped gene enhancers across 20 species to explain mammalian regulatory evolution (Villar et al., *Cell* 2015);

constructed a cellular differentiation map of all major embryonic lineages *in vivo,* providing a roadmap for regenerative medicine approaches (Pijuan-Sala et al., *Nature* 2019); and showed how bioavailability of a single amino acid–asparagine–regulates metastatic cancer progression (Knott et al., *Nature* 2018). And together with ***Mechanisms of Disease CCT*** detailed the molecular basis of the unfolded protein response to stress (Amin-Wetzel et al, *Cell* 2017; Zyryanova et al., *Science* 2018); and uncovered the role of RNA granules in ALS (Liao et al. *Cell* 2019).

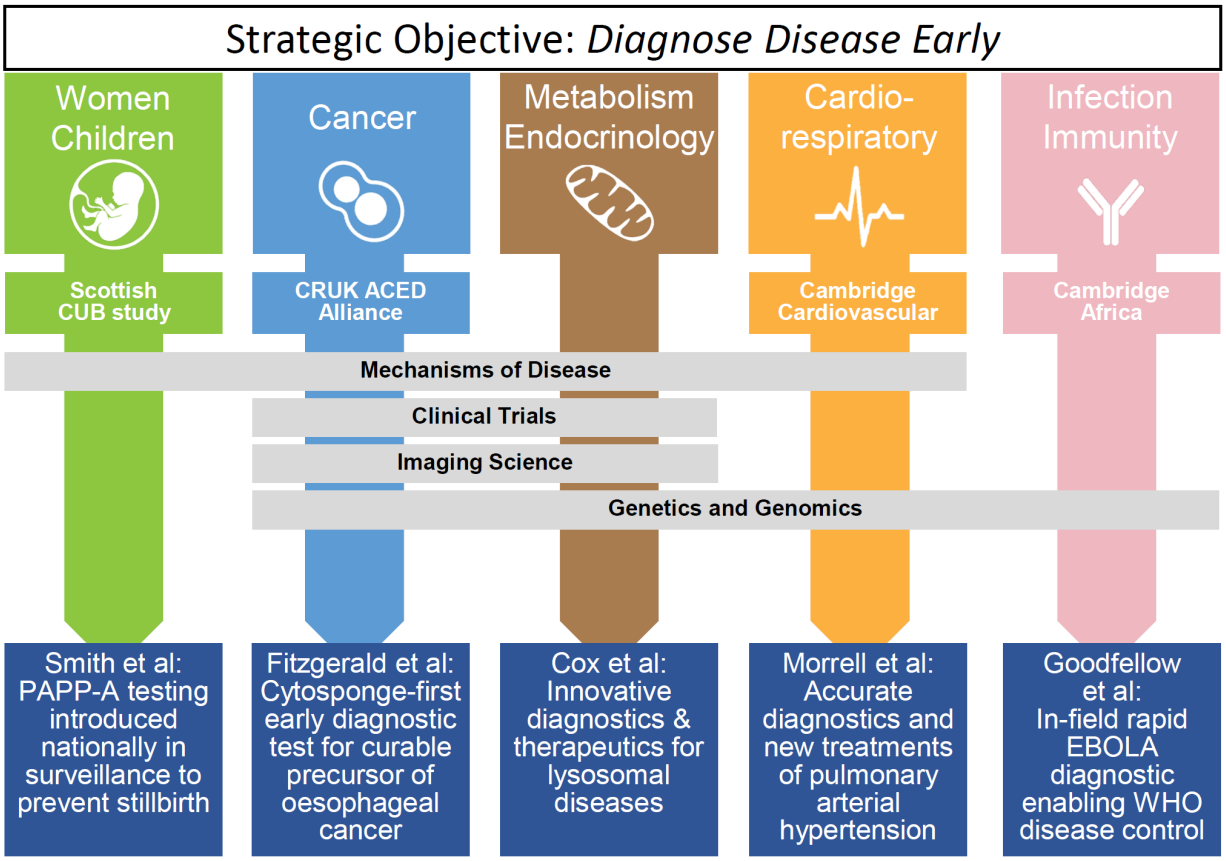

Figure 2 Strategy yields impact: Using the exemplar of our strategic objective to 'Diagnose Disease Early', figure shows how SRCs (top) utilise major networks and collaborations (below each SCR) and CCTs (grey bars) to achieve impact – as illustrated by five of our impact cases (bottom blue boxes).

- ***Genetic basis of disease*: *Women and Children's*** together with the ***Genetics and Genomics*** CCT, led the UK Prenatal Assessment of Genomes and Exomes Consortium to identify genetic causes of foetal malformations (Lord et al., *Lancet* 2019). Multiple SRCs discovered the genetic basis of a broad spectrum of rare diseases (Turro et al., *Nature* 2020) as well as relatively common cancers (Nik-Zainal et al., *Nature* 2016). ***Infection and Immunity*** advanced genetic diagnosis of sporadic primary immune deficiency (Thaventhiran et al., *Nature* 2020), describing more than 6 new genes causing disease, and continue to lead in defining the genetics of both susceptibility (Huang et al. *Nature* 2017) and outcome (Lee et al. *Nature Genetics* 2017) in inflammatory bowel disease. Cohort sequencing by ***Cancer*** identified clones with leukaemic potential in healthy people (Abelson et al., *Nature* 2018) and genomic prognostication systems of myeloproliferative neoplasms (Grinfeld et al., *NEJM* 2018), demonstrating the value of genomic sequencing for aetiological discovery, diagnosis and precision treatment.

- ***Biology of therapeutics and disease control:*** Through clinical trials and associated laboratory studies, ***Metabolism and Endocrinology*** demonstrated the utility and safety of the artificial pancreas (Thabit et al., *NEJM* 2015; Stewart et al., *NEJM* 2016; Bally et al., *NEJM* 2018); uncovered the mechanism of action of Metformin in causing weight loss**,** the world's most prescribed anti-diabetic drug (Coll et al., *Nature* 2020); and provided proof-of-principle that programmable nucleases can correct heteroplasmic mitochondrial mutations *in vivo* that underly incurable diseases (Gammage et al., *Nature Medicine* 2018)

- **We advanced early diagnosis:**
  - ***Prenatal diagnosis:*** The UK is 24th of 49 high income countries by stillbirth rate. ***Women and Children's*** identified and developed Pregnancy Associated Plasma Protein A levels to triage pregnancies at high-risk of stillbirth. This was recommended in a 2016 NHS England Care Bundle which was associated with >500 fewer stillbirths/year in England **(Impact Case Study Smith et al.).**
  - ***Neonatal and Childhood diagnosis: Metabolism and Endocrinology*** transformed the national thyroid diagnostic service to decipher ~200,000 discordant thyroid function tests each year in the NHS; now providing the service worldwide and preserving the growth and development of children with Thyroid Hormone Receptor heterozygous mutations who are now treated with high doses of thyroid hormone.
  - ***Early cancer diagnosis: Cancer*** conceived, invented and validated Cytosponge™ as the first US FDA and CE approved diagnostic test for curable, pre-oesophageal cancer lesions. Cytosponge™ is being implemented as a pilot service of 2,500 cases to relieve Covid-19 endoscopy restrictions in Scotland **(Impact Case Study Fitzgerald et al.)**.
  - ***Diagnosis for disease control: Infection and Immunity*** led an international '*in field'* lab in Sierra Leone during the 2013-16 Ebola epidemic that tracked the spread of Ebola, enabling rapid early diagnosis, and disease source containment, ultimately contributing directly to control of the epidemic **(Impact Case Study Goodfellow et al.).**

- **We developed ways to precisely treat:**
  - ***Autoimmune diseases: Infection and Immunity*** optimised existing, and developed new, treatments that have improved five-year survival and quality of life for patients with antineutrophil cytoplasmic antibody-associated vasculitides **(Impact Case Study Jayne et al.)**. Developed the first prognostic biomarker for newly diagnosed patients with inflammatory bowel disease (Biasci et al., *Gut* 2019).
  - ***Cancer:*** developed less invasive and more cost-effective ways to stage lung cancer: now adopted by the NHS and many other countries, reducing surgical procedures by 80% and saving the NHS >GBP1.2 million/year **(Impact Case Study Rintoul et al.)**; democratised access to precision medicine through online, NICE mandated treatment decision tools for cancer treatment (used >1.25 million times across the world since REF2014; **Caldas et al., Impact Case Study**); invented the InVisionFirst™-Lung Liquid Biopsy through a spin-out company that has raised >GBP75 million and employs 60 staff now deployed across the world to guide lung cancer treatment **(Impact Case Study Rosenfeld et al.)**; and led clinical trials involving >6,000 patients in >150 UK Centres to 'de-escalate' breast cancer therapy, preserving survival and reducing toxicity while reducing NHS costs by GBP46 million/year **(Impact Case Study Coles and Earl)**.

- **We developed new therapies:**
  - ***Rare, incurable disease: Cardiovascular and Respiratory*** showed bone morphogenetic protein type II receptor pathway mutations cause >25% of pulmonary arterial hypertension, leading to new diagnostic and treatment strategies **(Impact Case Study Morrell et al.)**. ***Metabolism and Endocrinology*** identified mechanisms underlying lysosomal diseases,

producing new diagnostic tests and treatments now approved internationally for the treatment of Gaucher and Niemann-Pick diseases (**Impact Case Study Cox et al**).
- ***Common disease: Metabolism and Endocrinology*** contributed to an online osteoporotic fracture risk calculator used by 66 countries, and a new therapeutic (romosozumab) approved Europe-wide (2019) to prevent osteoporotic fractures that cost the UK GBP4.5 billion/year, including: (**Impact Case Study Poole et al.**).

- **We integrated multidisciplinary care of chronic diseases including:**
  - ***Obesity: Metabolism and Endocrinology*** showed single-gene mutations can cause childhood-onset obesity, revolutionising understanding, diagnostic genetic testing and treatment of the disease (**Impact Case Study O'Rahilly et al.**).
  - ***Disorders of insulin action: Metabolism and Endocrinology*** research underpinned key policies, guidelines and education programmes for managing diabetes and developed "closed loop" insulin-delivery systems used across the world (Tauschmann et al., *Lancet* 2018); and identified genetic disorders of insulin action; founded a nationally commissioned clinical service for severe insulin resistance; and developed therapies for lipodystrophy and regional overgrowth (**Impact Case Study O'Rahilly**).
  - ***Renal failure:*** UOA1 collaborative research showed suitability of donor organs previously rejected for transplant, leading to ~950 more renal transplants per year, reducing morbidity and mortality and saving the NHS ~GBP17 million/year (**Impact Case Study Nicholson et al.**).

1.5.4. We invested in physical infrastructure

Since REF2014, our Research and Impact Strategy has yielded inward investment of ~GBP320 million to build new clinical and laboratory research space. A full description of this new infrastructure is provided in Section 3.3.2.

1.6. FUTURE AIMS

UOA1 will pursue its common mission (Section 1.1) guided by our Research and Impact Strategy (Section 1.4).

1.6.1. Maintaining and growing a world-class research environment

People and Networks: We will continue to grow our proven model of collaborative networks that enable the recruitment and retention of a high-quality workforce and the conduct of impactful research. Examples include, but are not restricted to:

- ***Cancer*** will mature its Early Cancer Detection and Integrated Cancer Medicine Programmes to reinvent the cancer patient care pathway within the context of the NHS. This will be enhanced by the new Cambridge Cancer Research Hospital that will include physical institutes dedicated to this research (below). We will grow newly established networks, including:
  - ***RadNet Unit (GBP6 million, established 2019)****:* ***Cancer*** hosts one of three major radiation oncology research units. Together with Manchester and London and additional funded centres at Glasgow, Leeds and Oxford we will recruit new research staff to advance understanding of radiation biology and cancer treatment.
  - ***CRUK Children's Brain Tumour Centre of Excellence (GBP3.4 million, established 2019):*** The only CRUK Centre dedicated to childhood brain tumour research is led from Cambridge in collaboration with the Institute for Cancer Research. Together with collaborators around the world, we will develop novel treatments for these tumours.
  - ***CRUK funded National Cancer Imaging Translational Accelerator*** (***GBP 10 million established 2018):*** will drive national first-in-man cancer imaging trials in the UK.

- ***Cardiovascular and Respiratory*** will recruit research groups to the Heart and Lung Research Institute (HLRI, Section 3.3.2) as a catalyst to further accelerate commercially relevant research that defines and validates cardiorespiratory disease mechanisms to advance prevention and develop novel diagnostics and therapeutics.

- ***Infection and Immunity*** will recruit to Cambridge Institute of Therapeutic Immunology and Infectious Disease (Section 3.3.2), thereby enhancing research on pandemics, antimicrobial resistance, and immune-mediated disease. It is deepening its links with the Sanger Institute.
  - ***Cambridge Institute of Therapeutic Immunology and Infectious Disease*** is growing its strength in global infectious disease research. It has joint appointments with Korea and India, and will open collaborative laboratory bases in Hong Kong and Singapore in 2021. It is developing key strategic alliances with two centres, in India and Africa, focussed on partnership and capacity building, to bolster its overseas research programmes currently active in around 20 LMICs.
  - Cambridge Institute for Medical Research has recruited a new Director (Rayner) who has revised the Institute strategy to include a focus on the biology of intracellular pathogens, particularly those prevalent in developing countries, and how they interact disrupt and hijack the normal organellar biology of their host cells.

- ***Metabolism and Endocrinology*** will work closely with the new Heart Lund Research Institute to collaborate on metabolic and cardiovascular research. It will build on its long-standing relationship with UOA2 and UOA4 to advance understanding of human appetite and food intake benefited by our new state-of-the-art facilities (Section 3.3.2). Links with ***Women and Children's*** and ***Cancer*** will focus on investigation of type 1 diabetes and obesity as a risk factor for cancer, respectively.

- ***Women and Children's Health*** **and NIHR Rare BioResource for Children and Young People** will recruit staff to expand deep-phenotyped and genomically-informed data science from conception to 25 years of age. It will grow interactions with the School of Biological Sciences, the Babraham Institute and the Wellcome Sanger Institute, to study the basic biology of reproduction, facilitated by the Centre for Trophoblast Research (see Section 4.2.1). And expand interactions with UOA4 to support physical-mental healthcare research in the new Children's Hospital.

Investment in physical infrastructure:

- **Two New Research Hospitals:** The Department of Health and Social Care and HM Treasury have pledged >GBP200 million to build two major new clinical facilities on the Biomedical Campus during the next REF cycle:
  - ***Cambridge Cancer Research Hospital (CCRH)***: Announced September 2020 as part of the Hospital Infrastructure Programme (GBP120 million), Cambridge University Hospital in collaboration with the University will build a new CCRH immediately adjacent to AstraZeneca, Cambridge University Hospital and Royal Papworth Hospital. This 25,000m^2 77 bed and ambulatory care hospital and research facility will convene teams of clinicians, biologists, mathematicians, physicists, chemists and engineers at the patient's bedside to develop innovative care pathways that diagnose cancer early and treat patients personally and precisely, building directly on our multidisciplinary early cancer detection and integrated cancer medicine programmes established during the current REF period (Section 1.5.2).
  - ***Children's Hospital:*** With GBP120 million of approved NHS funding and GBP100 million philanthropy, Cambridge Children's will be the first purpose-built children's hospital in the world to fully integrate physical and mental healthcare and research. Studying the earliest origins of physical and mental health conditions and interventions it will seek to prevent health

risks from becoming disease. Genomic medicine and molecular mechanisms of physical and mental health conditions will constitute principle focuses of research, working in close partnership with Cambridge Institute for Medical Research to create an impactful research arc from genetic diagnosis through mechanistic understanding to new interventions. Connected to the adjacent Rosie Maternity Hospital and NICU the combined Medical Centre for Women's and Children's Health will comprise >45,000m^2.

- ***Cambridge Movement Centre:*** in collaboration with Cambridge University Hospital, this planned GBP150 million 18,000m^2 facility will lead innovative musculoskeletal research and care, including stratified approaches to advanced cell, regenerative and disease modifying treatments for osteoarthritis and other musculoskeletal diseases (Section 1.5.2.).

- ***Investments in CCT infrastructure: Genetics and Genomics*** will further establish and grow the East of England Genomic Medicine Centre and deliver the commissioned NHS East Midlands and East of England Genomic Medicine Laboratory hub. ***Imaging*** plans to invest in a new cyclotron and PET CT machine, expand our radiopharmaceutical unit to supply new radiotracers and MRI probes, and further update our MRI machines to ensure that our imaging facilities are optimally placed to support and deliver the highest quality research.

1.7. FOSTERING AN OPEN RESEARCH ENVIRONMENT

UOA1 is committed to upholding the principles of Open Science beyond the requirements of the REF Open Access Policy. To this end, UOA1 is represented by Prof David Owen on the University-wide Open Research Steering Committee (ORSC) that works to:

- **Promote and implement** effective policies on: Open Access and Research Data Management; compliance with external mandates; and overview of best practice.

- **Facilitate** close working of all internal services supporting Open Research.

- **Understand** researcher needs, supporting diversity of practice and ensuring compliance.

- **Identify** information systems to support Open Research, and to monitor rolling five-year plans, acting as first point of resolution for resource issues.

- **Oversee:** University public communications on Open Research; annual (or more) reviews of the University position statement on Open Research; and monitor development of external policy frameworks.

UOA1 and UOA4 collaborate on an annual 'Open Science Day' that hosts workshops spanning pre-registration, data sharing, reproducible research and open publication. The workshop also provides a platform for discussion and the opportunity to share experiences across all aspects of Open Science.

1.7.1. Open Access

Together with the ORSC, UOA1 is working to implement the key principles of Plan S, including agreements with journals to publish open access with no charge and schemes with publishers to reduce the cost of publishing open access. We promote both Green and Gold Open Access via a network of 13 Open Access Champions, positioned strategically across UOA1 Departments, Institutes and Units. >85% of UOA1 publications since 2015 have been deposited via the Green

Route (uploaded to Apollo, the University's Institutional Repository). UOA1 also benefits from the University Library '***Request a Copy***' service, allowing the distribution of embargoed manuscripts on an individual-to-individual basis. Between June 2016 and September 2017, the University received 3,240 requests for manuscripts: two of the top three were from UOA1 (Mackay et al., *American Journal of Epidemiology*, 2016; Kuchenbaecker et al., *JAMA* 2017); producing, strong feedback from professionals (e.g., 'I'm a paediatric radiation oncologist and this paper is a "practice changer"!) and lay persons (e.g., 'Our daughter is being investigated for Beckwith-Wiedemann Syndrome and we would like as much information as possible about this disease').

1.7.2. Open data and software

UOA1 promotes good research data management including the FAIR (*F*indable, *A*ccessible, *I*nteroperable, and *R*e-usable) research principles via a network of 12 Data Champions, supported by the University Research Operations Office. This ensures that UOA1 adheres to all University, NHS and funder data access policies. Through the NIHR BioResource–Rare Diseases we have provided sequence data on >13,000 patients with rare diseases as a research resource and to accelerate new genetic diagnoses globally; and the NIHR BioResource includes over 120,000 individuals who have given consent to be contacted for future research. Box 1.3 includes other, exemplar UOA1 accessible online research databases.

BOX 1.3: Examples of UOA1 created open online research databases:

Mitominer, an integrated online-database of mitochondrial disorders and phenotype data for mammals, zebrafish and yeasts, enabling sophisticated data mining queries spanning many different sources.

National Cancer Imaging repository (NCITA) enabling sharing of cancer imaging with meta-data across collaborating sites

EPICOV a unique download of the anonymised electronic health records of 150,000 patients to facilitate COVID, epidemiological and operational NHS research.

SOMX a collaboration between UOA1 and UOA2 that is developing, refining and maintaining novel 'omic analytical tools (https://www.mrc-bsu.cam.ac.uk/research-and-development/somx-statistical-omics/).

CC-MEDIA a mammography repository from 120,000 women to benchmark AI algorithms and develop new software to aid screen reading.

1.7.3. Research reproducibility

Since REF2014 UOA1 has actively established a culture of research reproducibility. We are not aware of any UOA1-led research studies that have been retracted since REF2014; however, we are cognisant that only a small proportion of research that is irreproducible is retracted. Therefore, we seek actively to maintain reproducibility by:

- ***Underlining the importance of research reproducibility:*** considering the issue regularly at governance and strategy meetings and encouraging all researchers to question the reproducibility of their own and colleagues' experiments.

- ***Training in reproducibility:*** through high profile external experts who lead workshops on research reproducibility e.g., Glen Begley (former global head of haematology and oncology at Amgen), who reported in *Nature* that Amgen could only reproduce 6 of 53 landmark preclinical cancer studies. And, providing annual research integrity and statistical and data

analysis training and support to all researchers, and mandating such training for all PhD students. We also promote the scrutiny of primary data in all supervisory and research group meetings.

- ***Enabling reproducibility:*** for example through the adoption of electronic laboratory notebooks (ELNs). Both the Cambridge Stem Cell and CRUK Cambridge Institute's completed extensive evaluations of ELNs, developing freely accessible guidelines to help researchers select the best solution for their research groups.

- ***Embedding in our culture*** for example by revising academic promotions and appointments criteria e.g. specifying that journal names and impact factors are not to be used as surrogate measures of quality.

1.8. SUPPORTING A CULTURE OF RESEARCH INTEGRITY

1.8.1. Overall approach to research integrity

UOA1 maintains the highest level of commitment to research integrity, regarding it as a vital measure of individual researcher performance. We foster a culture of research integrity that pervades UOA1, upholding the commitments outlined in the UK's *Concordat to Support Research Integrity* through a comprehensive 'top-down and bottom-up' approach that encourages a sense of responsibility for upholding the key principles among all researchers.

Setting standards by leadership*:* The School hosts a Research Governance Team led by Dr. Carolyn Read who work alongside the Research Integrity Officer to provide specialist guidance at all stages of the research cycle. UOA1 also benefits from established organisational initiatives for maintaining high standards of integrity. For example, University and School Research Ethics Committees review research proposals using healthy volunteers, while NHS Research Ethics Committees review those using patient data. All animal research is reviewed both before commencement, and after completion, by the University Animal Welfare and Ethical Review Body (AWERB) consisting of scientists, veterinarians and lay persons with a particular focus on the 3R's (reduction, refinement and replacement). Cambridge has received 'Leader in Openness Awards' from the Concordat on Openness on Animal Research for its commitment to promote openness and transparency in animal research. UOA1 recognises also that demonstrable commitment to research integrity by senior leaders is fundamental to embedding a culture of integrity. Therefore, Profs. Smith (***Women and Children's***) and Jodrell (***Cancer***) are members of the Cambridge University Hospital Research Compliance Committee.

Embedding integrity at the grassroots: Each UOA1 Department, Institute and Unit fosters a local culture of research integrity e.g., Cambridge Stem Cell Institute Research has a Culture and Integrity Committee that hosts a monthly seminar series 'Empowering Research' that promotes an an open, high integrity, research culture. In addition, all new PhD students undertake compulsory research integrity training.

1.8.2. Dealing with allegations of research misconduct

Allegations of research misconduct within UOA1 are governed by the University's *Misconduct in Research* Policy. Allegations are first reported to the Head of Department and/or the Head of School and potential cases to be answered are investigated with support from the Research Policy, Governance and Integrity Officer in the University's Research Strategy Office. Where concerns are identified these are immediately disclosed to funders, and other regulatory bodies where appropriate e.g., the GMC's Responsible Officer. Individuals whose behaviour does not reach the threshold of research misconduct, but raises concern over scientific standards, are provided with training, support and monitoring.

2. People

2.1. OVERARCHING STAFFING VISION AND STRATEGY

2.1.1. Staffing Vision and Strategy

UOA1 staff and students are its most valuable asset and inspire our Staffing Vision to create '***a great place to do great work***.' Our Staffing Strategy spans from recruitment, through staff appraisal and mentoring, to rewarding and promoting staff. It is aligned purposefully with the overarching principles of the Concordat to Support the Career Development of Researchers (CSCDR) to provide: *a supportive and inclusive research environment; recruit, employ and manage researchers in a manner that recognises and values their importance; and enables researchers to realise their professional potential through career development.* The University received the European Commission's Human Resources Excellence Badge in recognition of this approach. Building on our REF2014 Environment Statement Staffing Strategy, UOA1 aims to:

- **Recruit a world-class research staff that promotes excellence, celebrates diversity, enables the individual:** Our ability to conduct research that has a positive impact on human health relates directly to the excellence and success of our staff. Throughout Section 2 we detail our approach to ensure the professional success of our staff. To optimise staff success from the start, we pursue a recruitment policy aligned closely to our Research and Impact Strategy.

- **Create a nurturing, diverse and inclusive research environment:** We purposefully create, promote and protect an environment that maximises the potential of a diverse and inclusive staff. This includes the provision of comprehensive mentoring and reward schemes as well as opportunities to develop professional skills.

- **Promote interdisciplinary research and team science:** Collaborative research networks lie at the heart of our Research and Impact Strategy. Therefore, our Staffing Strategy supports this approach to ensure that staff benefit from, and contribute to: the excellent quality of our research environment; cross-department and cross-school appointments; and interactions across all levels of staff and students.

- **Build and maintain strong and sustainable links with allied stakeholders:** Our Research and Impact Strategy is dependent on strong, mutually beneficial partnerships with allied clinical and laboratory stakeholders to effect important healthcare, policy and economic change. As such, we promote partnerships between our staff and peer-academic and NHS institutions e.g., through honorary clinical appointments for medically-qualified academics, industry, and government and professional bodies.

Our Staffing Strategy is co-led by Caroline Newman (Director of Human Resources) and Prof. Fiona Karet ('Director of Organisational Affairs' a post created in 2015). By dovetailing our Staffing Strategy and Athena Swan Action Plan (Silver award 2013, renewed 2016) we have united Staffing Strategy efforts across UOA1. Our Athena Swan awards and 2019 University Staff Survey testify to the success of our approach, with 90% of staff (308/342, 88% return rate) stating they '*were proud to work at the University*'. Only 17% and 4% stated they felt undervalued or not treated with fairness and respect, respectively. Nevertheless, these observations have driven our recently launched ***'Respect at Work'*** Campaign which is designed to maximise positive interpersonal behaviours.

2.2. STAFF RECRUITMENT AND PROGRESS

2.2.1. Recruitment processes

UOA1's united leadership (Strategic Pillar 2, Section 1.4.2) ensures that staff recruitment is based on collaboration, complementarity and equality, and focuses on research priorities, thereby promoting interdisciplinarity and sustainability. Our recruitment processes are required to be broad and open, communicating the University's policy to welcome and enable candidates with protected characteristics. This is assisted by our use of social media: our LinkedIn posts generate an average of 593 views/vacancy with a 5% successful shortlisted click rate**.**

All UOA1 **long and short-listing processes** are conducted according to best practice. Electoral boards for professorial appointments are required to specify how they have addressed diversity and inclusion. All recruitment and selection panel members are required to complete Equality, Diversity, Inclusion and Unconscious Bias Training. Panels are constituted carefully to ensure diversity, while avoiding burdening senior women, by requiring a proportionate gender balance.

Interviewing and assessment approaches are tailored to each appointment. Early career researcher (ECR) interviews include chalk talks and/or departmental seminars while faculty academic appointments follow a two-stage process including both departmental and school-level interviews. This consistent approach ensures equality in appointments across UOA1, and communicates to all candidates our commitment to education, clinical care and a positive culture.

Particular attention is paid to Clinical Lecturer appointments. A School-level panel chaired by the Regius Professor includes the regional Health Education England postgraduate Dean and relevant training programme director, thereby ensuring appropriate arrangements exist for clinical training and researcher development.

On appointment, all academic appointees are allocated a mentor from outside their line management arrangements to provide independent advice and support.

2.2.2. Recruitment since REF2014

Since REF2014, UOA1 has recruited 90 new staff (72 research and 18 research and teaching [22 at the rank of professor]). Thirty-four strategy-driven, senior academic recruitments were enabled by endowments, competitive fellowships and retirement-replacement positions, with 32% (11/34) being women and 21% (7/34) being international. Testimony to the success of this approach is the number of senior leaders who have shaped directly our UOA1 research environment (Box 1.2).

We have also recruited 569 early career researchers (ECRs), representing 30% of all recruitments, including 64% women. Sixty (11%) ECR recruits are funded through external fellowships from the MRC, CRUK, Wellcome Trust, UKRI Future Leader, Leverhulme, and NIHR. This growth has been facilitated directly by our Research and Impact Strategy that has enabled the attraction and recruitment of ECRs to strong collaborative teams within SRCs and CCTs (Section 1.3.1) and our major new infrastructure investments on the Biomedical Campus (Section 3).

We are also passionate about recruiting apprentices and maximising the use of the apprenticeship levy to create entry level appointments to build our internal career pathways. To date we have recruited 12 new apprentices.

2.3. STAFF DEVELOPMENT

To ensure parity of opportunity and bespoke development offerings, UOA1 staff are provided with opportunities at the University, School and Departmental level. Seventy-eight percent (266/342) of UOA1 staff responding to our recent survey were positive about their career development opportunities and promotion processes.

2.3.1. University-wide development opportunities

The University hosts 2,772 courses (including 68 personal and professional development courses) for staff across nine themes including: Achieving Results, Communication, Innovation and Change, Leadership, Negotiating and Influencing, People Development, Relationship Building, Strategic Focus and Valuing Diversity. Courses span three levels of leadership training for mid-career and senior academics. In addition, UOA1 staff benefit from the University sabbatical programme that also facilitates exchange and collaboration with external academic partners (see Section 2.6.1).

2.3.2. School of Clinical Medicine Induction, probation and appraisal programme

The School leads a systematic approach to induction, probation and appraisal across UOA1 to ensure we meet the development needs of our diverse and multi-disciplinary staff, while providing an equitable and fair development foundation.

The **induction programme** includes online and in-person modules. Seventy-three percent (250/342) of staff said this programme provided all the information needed to do their job effectively. This is supplemented by welcome events for all new starters. One new starter noted '*I really valued the Regius' emphasis on kindness, generosity, inclusion and diversity.*'

Currently, 91% and 87% of **probations and annual appraisals** are completed in UOA1: 72% (246/342) of staff confirmed their appraisal was productive. The appraisal form now includes sections acknowledging the impact of career breaks and the coronavirus pandemic. The School leads regular interactive training seminars for staff who are line-managers.

Mentoring and support structures include: schemes for mid-career staff–a group often underserved in professional development; 'Learning to Fly' career development programmes for mid-career women seeking academic leadership roles; and bespoke media training for senior academics.

2.3.3. Bespoke development opportunities in UOA1 Departments, Institutes and Units

Each constituent element of UOA1 offers bespoke mentoring and development opportunities tailored to the needs of our diverse staff in their actual site of working. These include part-time higher degree opportunities for staff:

- ***The Genomics CCT (Section 1.2):*** HEE-commissioned Genomic Medicine Masters and part-time courses (PGDip, PGC, CPPD) hosting 286 unique students. Enabled a diverse group of staff to access world class education, including 35 MPhil/MSc students who proceeded into PhD studentships/graduate entry medicine. The programme has established a widening participation initiative in genomic medicine (Launchpad for Next Generation Medicine for pre-University students).

- ***Institute for Metabolic Science*** supported several research assistants to complete PhDs since REF2014 and introduced part-time PhD and MPhil degrees to enable research assistants and technical staff to obtain a higher degree alongside their employment.

- ***The Evelyn Cambridge Surgical Training Centre*** is a state-of-the-art, Royal College of Surgeons accredited cadaveric training facility that together with **The Cambridge Simulation Centre** delivers over 200 days of technology-enhanced learning to over 1,000 delegates each year.

- ***Institute for Continuing Education*** in collaboration with Cambridge University Health Partners delivers a Masters in Health Data and a PGCert in Healthcare Research, Education and Leadership.

- ***CRUK PhD and Clinical Academic Training Scheme:*** in 2019 the CRUK Cambridge Major Centre welcomed its largest ever cohort of 48 Centre students, including four new MB/PhD medical students.

- ***Master of Surgery*** with new regulations (2020) that expand eligibility criteria providing an opportunity for trainee surgeons and clinical surgical fellows to gain valuable research experience in a clinical or laboratory setting.

- ***Executive MBAs at the Judge Business School*** have directly impacted UOA1 staff development, enabling: Prof. Antonio Vidal-Puig to forge a scientific alliance with the Nanjing Centre of Technology and Innovation and Dr. Anna Petrunkina to expand the NIHR Phenotyping Hub with Singapore (SGD$8 million).

2.4. THE WELLBEING PROGRAMME

We recognise the importance of supporting staff wellbeing as part of creating a workplace which is conducive to the production of world-leading research. In 2015 UOA1 launched a new Wellbeing Programme that included a focus on mental health. Expanded in 2016, the programme includes seven core wellbeing objectives:

- ***Increase*** the confidence of employees and students, thus enabling them to discuss mental health issues freely within the workplace.

- ***Provide*** appropriate training and support for managers and supervisors so they feel able to discuss concerns with and provide support to employees and students.

- ***Encourage*** positive wellbeing and encourage staff to access the University's staff benefits.

- ***Highlight*** the availability of effective interventions to managers, staff and students through increased and prominent of information.

- ***Support*** the strategy for health and wellbeing which forms a key strand of our Clinical School Athena SWAN Silver award.

- ***Promote*** and facilitate good physical health amongst all staff.

- ***Collaborate*** with organisations across the Biomedical Campus to promote wellbeing across the site.

The initiative is supported by Mental Health First Aiders who provide telephone-based confidential mental health support.

The Programme runs annual ***Well Being*** and ***Mental Health*** weeks, exercise classes, yoga, massage and board game sessions and hosts talks e.g., managing depression, self-harm, nutrition and obesity.

The success of our wellbeing initiatives has been recognised nationally by requests to share best practice through national organisations e.g., Universities and Colleges Employers Association national conference, and a chapter in the Trades Union Congress 'Guide to Workplace Health'.

2.5. SUPPORTING EARLY-CAREER RESEARCHERS (ECRs)

UOA1 ECRs comprise a diverse, international network of 457 postdoctoral and 34 clinical research associates. In addition to the opportunities outlined throughout Section 2, ECRs are supported with programmes tailored to the specific challenges faced at this level, including: career instability/limited short-term contracts; the expectation that individuals will move institutions frequently; concerns relating to limited funding and future career opportunities. These challenges are further complicated for ECRs who balance research and clinical training. Therefore, these individuals benefit also from the support of our Clinical Academic Training Office (Section 2.5.4).

2.5.1. ECR Induction, probation and appraisal

All new ECRs are offered induction and training programmes within their host Department, Institute or Unit that orientate them to local procedures, policies and support structures including access to neutral and impartial confidantes. Our robust probation processes and annual appraisal exercises ensure consonance between the expectations and responsibilities of staff and their line-managers.

2.5.2. ECR pastoral and mentoring support

Principal investigators and line-managers, supported by the School, provide comprehensive mentoring programmes so that ECRs develop their strengths, and address potential weaknesses, in a safe and open environment. Opportunities include:

- **Mentored committee service** so that ECRs can learn how research environments are organised and managed e.g., Research Governance and Integrity committees. Such opportunities are provided strictly in the context of mentoring, ensuring that ECRs benefit without distracting them from their research.

- **Grant writing mentoring programmes** are provided to ECRs. The ECR Grant Writing Group led in 2018 by Gender Champion Dr. Heike Laman, focused on all newly-appointed female ECRs who subsequently secured >GBP2 million in grants.

- **Work in Progress talks** as well as Annual Retreats provide ECRs with the opportunity to present their work and receive feedback from senior researchers and peers and gain experience chairing symposia.

- **ECR specific committees** identify and highlight to UOA1 leadership issues of particular importance to this group of staff.

2.5.3. The Postdoctoral Academy

The Academy supports all aspects of postdoctoral life and development from welcome, induction and orientation, through professional development, training and bespoke mentoring. Advocacy and support on matters of policy relating to postdocs, including internal university and national policies, is also provided. ‘Life beyond Cambridge’ programme links members with prospective employers, funders and fellow alumni. The Academy also supports the Postdocs of Cambridge Society,

Entrepreneurial Postdocs of Cambridge, and the Postdoc Chairs' Network to broaden reach and impact. The Academy recently expanded to offices on the Biomedical Campus, Central Cambridge and Eddington close to the University's post-doctoral housing development; thereby providing ECRs with free meeting rooms for networking and social events close to where they work. The Academy coordinates the University Postgraduate Open Day at which external applicants can visit the Biomedical Campus and meet potential supervisors.

BOX 2.1: Exemplar funding for ECRs:

FLIER: Charlotte Summers (now a UOA1 University Lecturer in Intensive Care Medicine) developed her impressive leadership attributes through the FLIER scheme, and has since established a successful research group, a spinoff company, Exvastat (Box 4.2), and has been appointed to the COVID Therapeutics Advisory Panel advising the Chief Medical Officer.

Borysiewicz fellowship: Established 2018, annually offers up to eight postdoctoral fellows a tailored programme of unique engagement opportunities and personal funding to develop as future research leaders. Gita Khalili Moghadd subsequently secured a three-year UKRI Innovation Scholar secondment to GlaxoSmithKline to use AI to develop new drugs for treating tuberculosis.

Experimental Medicine Training Initiative: This GBP5 million partnership between the University, NIHR-BRC, AstraZeneca and GlaxoSmithKline support clinical PhD students and lecturers to become independent clinical researchers.

Pathology Research Fellowship Scheme: Funded by royalty patent income, provides 5 years funding to senior postdocs. Supported five male and four female fellows since REF2014: three of whom have already gone on to win external fellowships.

MRC Metabolic Diseases Unit "Directors Award" provides GBP10,000 to post-doctoral scientists to initiate their own collaborative research.

Helena Earl Fellowship provides an unrestricted GBP10,000 award to a female ECR to support career development through research costs, childcare or other expenses.

2.5.4. Clinical Academic Training Office (CATO)

CATO oversees the Academic Foundation Programme (AFP), Academic Clinical Fellowship (ACF) and Clinical Lecturer (CL) programmes for clinician scientists. This combined oversight provides a seamless pathway, integrating with local and national MPhil and PhD programmes and allowing trainees to forge a career as clinical academics. CATO provides comprehensive administrative support, including managing complex interactions across the University, NHS trusts, Health Education England and the NIHR. With a current budget of ~£40M, CATO manages the annual bid for NIHR Integrated Academic Training Programme awards that has increased significantly since REF2014: AFPs increased from 12 to 24 and ACF and CL doubled to 100 and 50, respectively. The majority of our programme graduates take up senior academic positions at other leading Institutes and our CLs have been awarded 65 Wellcome Trust/AMS starter grants since 2008, the largest number granted to any UK HEI in that time period.

2.5.5. Protected funding for ECRs development

Every year the School funds ECRs to join carefully selected national and international training schemes. These include: EUREKA translational medicine training programme in Syracuse, Sicily; British Science Association Media Fellowships scheme; and the Academy of Medical Sciences Future Leaders in Innovation, Enterprise, and Research (FLIER) scheme; as well as several competitive fellowships designed to support the most promising and innovative ECRs (Box 2.1).

2.6. FACILITATING EXCHANGE BETWEEN ACADEMIA AND EXTERNAL PARTIES

2.6.1. Research leave and sabbatical

All senior UOA1 staff have to access sabbatical leave (one term every six) at institutions of their choice. These opportunities frequently produce new collaborations that enhance our research environment. Close partnership between UOA1 and our NHS partners (Section 1.3) enables planning of clinical responsibilities so that clinical academics also benefit from sabbatical leave. Examples include:

- ***Cancer:*** in 2019 Caldas spent four months at the Weizmann Institute, resulting in that Institute becoming an external site for our PARTNER Breast Cancer clinical trial run through the Mark Foundation Institute for Integrated Cancer Medicine (Section 1.5.2).

- ***Cardiovascular and Respiratory:*** in 2016 Morrell spent six months at the Wellcome Sanger Institute collaborating with Nicole Soranzo, greatly benefitting his studies of pulmonary arterial hypertension that underpin one of our Impact Case Studies (Section 1.5.2).

- ***Metabolism and Endocrinology:*** Karet's sabbatical in 2017 surveyed working culture initiatives in US and Australian Universities, resulting in a re-emphasis of culture in our Staffing Strategy, the bringing forward of our Apprenticeship programme and improving our recruitment practices.

2.6.2. Interactions with peer-academic institutions

Our Research and Impact Strategy emphasises the importance of partnership among academic, NHS and industry collaborators (Section 1.3), and much of our impact since REF2014 has been delivered through multi-disciplinary teams (Section 1.5.2). These teams enhance our ability to recruit and retain an outstanding workforce and compete for major external grants (Section 3). UOA1 teams unite academics from across UK and international institutions as well as industry, for example:

- ***Cancer:*** The CRUK Cambridge Major Centre connects >800 university staff across all six Schools of the University and beyond, led by Prof. Gilbertson (Box 1.2). Members include senior staff, ECRs, and students as well as Category C staff organised into 12 programmes: eight focus on the commonest and most challenging cancers; four are discipline-specific, e.g., Advanced Cancer Imaging (led by Prof Evis Sala, Box 1.2). This structure has secured external grants and established international collaborations, including: **The International Alliance for Cancer Early Detection (Section 1.5.2)**, a GBP55 million international network uniting >900 clinicians, biologists, epidemiologists, mathematicians, engineers, chemists, and physicists (UOA1,2, 5, 8-12) with academics across partner UK and US institutions to tackle the biggest challenges in early detection; **The Mark Foundation Institute for Integrated Cancer Medicine**; and **The CRUK Children's Brain Tumour Centre of Excellence (Section 1.5.2)**.

- ***Infection and Immunity:*** **MRC/EMINENT** collaboration between UCL, Cambridge, Glasgow, Newcastle, Imperial College London and GlaxoSmithKline, supporting the COMBIVAS experimental medicine study to examine the effects of combination therapy with rituximab (anti-CD20) and belimumab (anti-BLyS) in patients with ANCA-associated vasculitis. **European Vasculitis Society**, led by Prof Jayne, coordinates European clinical research in vasculitis, and the **European Vasculitis Genetics Consortium**, established by Prof Smith, is pioneering genetic studies in this group of serious diseases.

- ***Metabolism and Endocrinology SRC:*** One of 35 European, US and Australian Institutions in the EU-supported **Early Nutritional Programming Consortium** (February 2012-January

2017). As part of a EUR1.1 million funded project on **Biomarkers for Infant Fat Mass Development and Nutrition** together with Erasmus University, The Netherlands and Danish Technical University. This SRC also leads the **International Research Consortium into Neurological Aspects of Gaucher Disease** that unites 31 institutions across 16 countries throughout Europe, North America, Middle East and Asia; and an ECR focused **Cambridge-Danish Diabetes Academy Metabolism Network** supported by the Novo Nordisk Foundation. This Is part of a growing relationship between Cambridge and Denmark, fostered by O'Rahilly's membership of the Novo Nordisk Foundation Scientific Advisory Board.

- ***Women and Children's Health SRC*:** Five members are principal investigators in the **Centre for Trophoblast Research**. Interactions across UOA1 and beyond have yielded several major collaborative grants e.g., Wellcome Investigator award with Pathology and world-firsts including establishing human endometrial and trophoblast organoids (***Nature Cell Biology*** 2017; ***Nature*** 2018). Members also lead the **INNODIA IMI2 Consortium** (Section 1.5.2).

2.6.3. Interaction with NHS institutions and inclusion of Category C staff

UOA1 partnership with the NHS is facilitated greatly by the co-location of UOA1 staff and our two NHS Foundation Trust Teaching Hospitals on the Biomedical Campus (Section 1.3). Clinical researchers within each of our SRCs are integrated within the NHS clinical service, 27% of UOA1 staff hold honorary clinical contracts, with 85% and 60% of principal investigators in ***Cardiovascular and Respiratory*** and ***Infection and Immunity***, respectively being clinically active. This promotes a continuous focus on research relevant to human disease. In addition to UOA1 category A staff with honorary NHS contracts, the 15 clinical directorates (out of a total of 16) include clinical staff that interface directly with UoA1 researchers. Indeed, 119 research active senior clinical NHS staff in specialties related to UOA1 are funded, in part or completely, through NIHR funding our main partner Trust, Cambridge University Hospitals. Clinical researchers have access to the same induction and development opportunities as non-clinically-qualified staff. In addition, the School and relevant NHS/Public Health England annual appraisals are coordinated, ensuring a holistic appraisal process. This includes proactive job planning to ensure that research time is protected for clinical investigators.

2.6.4. Interaction with Industry

The University has a long and highly-productive history of interacting with industry, conducting research that has underpinned the establishment of biotechnology and pharmaceutical companies. Currently, there are >440 life science and health-care companies in the wider Cambridge area. Ten of our 14 Impact Case Studies have generated spin off companies or contributed directly to the successful development of a commercial diagnostic or therapeutic. Interactions between UOA1 staff and industry are facilitated greatly by the collaborative research networks that underpin our Research and Impact Strategy (Section 1) and the School's Office for Translational Research, working closely with Cambridge Enterprise (Sections 3.4.2. and 4.3.2). Additional strategic approaches to enhance collaboration with industry include:

BOX 2.2: Leaders in industrial partners who co-lead UOA1 initiatives include:

Regina Fritsche-Danielson (Senior Vice President, Research and Early Development, AstraZeneca) serves on the Scientific Advisory Boards of both the Cardiovascular and Metabolism and Endocrinology SRCs

Susan Galbraith (Senior Vice President and Head of Research and Early Development, Oncology at AstraZeneca) serves on the Executive Board of the Cancer SRC

David Bentley (Chief Scientist at Illumina) advises precision medicine efforts of our East Midlands and East of England Genomic Laboratory Hub.

- ***Open and shared leadership:*** Leaders in major industrial partners on the Biomedical Campus serve on key UOA1 governance boards (Box 2.2). These interactions have led directly to UOA1 research collaborations including: the Cambridge Centre for AI in Medicine and the Mark Foundation Institute for Integrated Cancer Medicine (Section 1.5.2).

- ***Co-design and occupancy of major infrastructure:*** We engage directly with industry and NHS partners when planning major infrastructure on the Biomedical Campus; thereby ensuring a collaborative, sustainable environment. Key examples discussed also in Section 3 include: AstraZeneca's world Research and Development headquarters (opening in 2021 with capacity for 2000 scientists); GlaxoSmithKline's first-in-human clinical trials unit embedded in Cambridge University Hospital; The Milner Therapeutics Institute hub of 80 affiliated organisations working across academia and industry; the Heart and Lung Research Institute that has received co-investment from industrial and research foundation partners including the BHF, Cystic Fibrosis UK, AstraZeneca and GlaxoSmithKline (opening December 2021). We are similarly working with industry and NHS partners in the creation of new Cambridge Cancer Research and Children's Hospitals (Section 1.6.1).

- ***Strategic Alliances:*** UOA1 has made mutually beneficial, strategic alliances with major biopharmaceutical companies aligned directly with our Research and Impact Strategy (Section 1 and Box 2.3). The School enables staff to work in industry on a part-time basis, as consultants and Board members, or on secondment with the option to return. For example: Prof. Maxwell provides life science expertise as a non-executive director of Scottish Mortgage, a GBP18 billion FTSE 100 company which is the largest investment trust in the UK and is focused on identifying and supporting breakthrough technologies and Prof. Eisen, seconded to AstraZeneca for five years, is now Head of Genitourinary Oncology at Roche. In addition, numerous UOA1 researchers engage with industry partners in collaborative research. For example, ***Metabolism and Endocrinology*** researchers have a longstanding relationship with an array of companies to understand the therapeutic value of GLP1-GIP targeting in metabolic disorders, including: clinical trials with Eli Lilly evaluating GLP1-GIP agonists for treating diabetes, obesity and NASH; studies of antagonistic antibodies against the GLP-1 receptor with AstraZeneca.

BOX 2.3: Exemplar UOA1 strategic alliances with industrial partners:

AstraZeneca (AZ) and Cancer: The CRUK Cambridge Institute has co-hosted 60 AZ scientists alongside UOA1 staff researching cancer (Section 1.3). Collaborations initiated by this co-location have underpinned the investment of GBP6 million by the company in the UOA1-founded Mark Foundation Institute for Integrated Cancer Medicine that is testing AZ novel treatments in prospective clinical trials. In 2020, the CRUK Major Centre became an international AZ Partner of Choice (Section 4.2.2) gaining access to new therapies being developed by the company. In addition, AZ have committed to place up to 50 of their scientists in the new Cambridge Cancer Research Hospital (Section 1.6.1).

GlaxoSmithKline (GSK) and Infection and Immunity: UOA1 and GSK have a long-standing relationship strengthened by the presence of GSK's only clinical trials unit worldwide, which is situated in the NIHR/Wellcome Trust Clinical Research Facility (Section 3.3.2) and the proximity of GSK's UK R&D hub close by in Stevenage. In 2015 the relationship developed into the GSK Strategic Alliance driven by the formation of the Cambridge Institute of Therapeutic Immunology and Infectious Disease (Section 1.6.1). Immunology is a key pillar of GSK's R&D strategy. From 2015-2020 the GSK 'Varsity Funding Programme' has provided GBP 10 million to support 31 focused research collaborations across the breadth of GSK's strategic areas.

- ***Co-mentoring and training*** with industry partners as part of our ECR development. For example, Collaborations with AstraZeneca currently consist of >100 active research projects engaging 70 funded PhD students.

2.6.5. Interaction with Government and professional bodies

UOA1 staff drawn from each of our SRCs serve key roles in important policy and decision-making bodies providing impact beyond Cambridge. As examples:

- ***Cancer:*** Fitzgerald served on the Screening Advisory Body Task Force advising on national cancer screening while Gilbertson served on the NHS Long-Term Cancer Planning committee and Chairs the NHS Innovation Expert Advisory Group.

- ***Cardiovascular and Respiratory:*** Summers is a member of UK-CTAP, advising government on the selection of new therapies to be tested in national COVID trials, and clinical advisor to the UK Government Ventilator Programme.

- ***Infection and Immunity:*** Peacock is Director of the National Infection Service and Executive Director and Chair of the COVID-19 Genomics UK Consortium and Public Health England Director of Science (Pathogen Genomics); Maxwell sits on the Executive Committee of the Medical Schools Council; Karet is a member of the Advance HE Athena Swan advisory group; Lehner and Dougan sit on the MHRA Committee evaluating COVID-19 vaccines.

- ***Metabolism and Endocrinology:*** Evans is Chair, Department of Transport Honorary Medical Advisory panel on driving and diabetes.

- ***Women and Children's:*** Smith has advised the Under-Secretary of State and Welsh and English parliamentary committees on stillbirth and maternity safety and co-organised a Department of Health and Social Care sponsored Stillbirth workshop. Rowitch and Raymond led the Next Generation Children's Project (2019), which piloted rapid turnaround (TAT) whole genome sequencing which resulted in commissioning of rapid genome diagnostics as a national service.

2.7. RECOGNISING AND SUPPORTING IMPACT

To nurture the vitality and sustainability of our environment we actively promote and reward our staff whose research results in exceptional impact achievements.

2.7.1. Promoting staff

Since REF2014, UOA1 has made 71 academic promotions (34 Senior Lecturers/Readers and 37 Professors) across the range of UOA1 research disciplines. To maximise staff promotion opportunities, the University runs a CV-mentoring scheme for senior academic promotion candidates, while the School runs senior promotions workshops for staff before each promotions round. Each year, all UOA1 Departments, Institutes and Units are required to review all female academic staff individually to consider whether they should be encouraged to apply for promotion; thereby addressing the possibility that they may be less likely to put themselves forwards than men. As a consequence, in 2020 the School had the highest promotions success rate in the University: 83% of our professorial and 88% of readership promotion candidates were successful. Further testimony to the success of our research environment is our 'export' of UOA1-trained members who are appointed to senior academic positions in other research institutions (Box 2.4).

2.7.2. Other staff reward mechanisms

BOX 2.4: Examples of former UOA1 academics moving to major leadership positions at other HEIs:

Prof. John Todd appointed Professor of Precision Medicine and Director of Wellcome Centre for Human Genetics Oxford in 2015.

Prof. Edwin Chilvers was appointed as Head of the National Heart and Lung Institute at Imperial College in 2018.

Prof. KJ Patel was appointed in 2020 as Director of the Weatherall Institute of Molecular Medicine and MRC Molecular Haematology Unit in Oxford.

In addition to staff promotion, UOA1 provides widely publicised staff reward opportunities that are staff-level appropriate and accessible to all:

- ***Opportunities for Senior staff:*** The School Nominations Committee meets quarterly to coordinate nominations for national and international prizes, honours, and membership of learned societies (e.g., Royal Society, Academy of Medical Sciences). To ensure equity, heads of departments provide statements summarising the most notable achievements of each member of staff. Nominees and suitable nominators are identified with support from the School and the Regius' office. Section 4.5 summarises some of our successful nominations since REF2014.
- ***Opportunities for professional services staff:*** The annual Professional Services Recognition Scheme recognises the very best work across all professional services, irrespective of Department, Institute or Unit.

- ***Reward of team science:*** The Vice-Chancellor's Impact and Public Engagement Awards Awards were established in 2016 and include award categories for staff at all career levels, including ECRs. Winners receive GBP1,000 to support further research impact activity and are widely promoted across the University (Box 2.5).

BOX 2.5: Vice-Chancellor's Impact and Public Engagement Awardees from UOA1:

2018 PREDICTProstate team from Cancer – an online cancer prostate cancer treatment decision tool visited >24,000 times from >100 countries and the source of one of our Impact Study Cases.

2019 Fritz's research in Cardiovascular and Respiratory led to the development of the ReSPECT process ("Recommended Summary Plan for Emergency Care and Treatment"), that has replaced problematic 'DNACPR' orders

2.8. RESEARCH STUDENTS

UOA1 hosts a vibrant and collaborative training environment for 358 PhD students organised through the School. Students are pivotal to our Research and Impact Strategy and we are committed to providing them with an outstanding foundation for a broad range of careers. Since REF2014, The School created a Director of Graduate Education role (Gribble, ***Metabolism and Endocrinology***) to lead this area, with a specific focus to ensure that student support is optimal and aligns closely with development and training needs.

2.8.1. Recruiting doctoral students

Our student recruitment strategy has several strands that ensure we host a diverse and talented group of students and position them for future success.

- **We deploy online and in-print recruitment communications to publicise training opportunities across the world**. Exploiting strong UOA1 national and international research networks ensures that candidates from around the world are familiar with our training opportunities. 59% of our candidates are recruited from overseas. For example, Reimann (***Metabolism and Endocrinology***) recruited a Research Assistant from Afghanistan who is now studying for a PhD.

- **We provide candidates with on-site, real-world experiential elements, mitigating biases towards internal applicants.** These include a highly successful summer internship programme to introduce external candidates to prospective supervisors and research teams.

- **We hold an annual University Post Graduate Open Day** on the Biomedical Campus, allowing candidates to build relationships with potential supervisors and explore areas of research interest prior to commencing their studies.

- **We monitor a range of protected characteristics among postgraduate training candidates and recruits to ensure equality and inclusivity of access to our training opportunities.** Over the last five years, 57.9% and 55.5% of applicants and those receiving offers, respectively, identified as female. 13.9% and 11.3% of applicants and those receiving offers, respectively, declared a disability. Recruitment of students with disability is facilitated greatly by the University's Disability Resource Centre which provides support for offer holders who have disclosed a disability at application. As a specific example, we recently supported a quadriplegic student on our MRC Doctoral Training Programme, for whom we made structural changes to the laboratory to accommodate his wheelchair, and provided an additional staff member as 'a pair of hands' to undertake his lab work.

- **We promote widening participation in recruitment through a summer scheme for disadvantaged students co-led by Deane (Wellcome Trust Senior Fellow).**

- **We recruit students to research teams and networks thereby promoting a culture of team science (see Section 2.2.2.).**

2.8.2. Studentships from major funding bodies

Reflecting the high-calibre of our doctoral cohort, 59% (213/358) of our students are supported by GBP5.4 million prestigious, external competitive awards (Table 1), while a further 17% (61/358) are supported with competitive local Departmental funds

- **School of Clinical Medicine MB/PhD Programme:** The University runs the first MB/PhD programme in the UK. Established nearly 30 years ago, the Cambridge MB/PhD has trained over 200 students many of whom now serve as academic leaders across the world.

- **The Wellcome Trust-funded PhD Programme for Physicians:** Established in partnership between the Universities of Cambridge and East Anglia and the Wellcome Sanger Institute, provides outstanding investigators as faculty mentors who provide mentoring, workshops and mini-projects to provide candidates with an informed choice of project and supervisor.

- **Cambridge MRC Doctoral Training Programme:** is a partnership between the University and the Babraham Institute, and includes as associate partners the MRC Institutes and Units in Cambridge, and other University Partner Institutes.

- **CRUK Clinical Academic Training and non-clinical Training awards:** Each year, the CRUK Cambridge Major Centre recruits: five non-clinical 4-year "3 + 1" MRes and PhD course students; two MB PhD students; six Clinical Research Fellows supported by a five-year budget of GBP 12.42 million.

Award Body	Sum of Amount	Count of Amount
MRC	£1,147,300	24.55%
Cambridge Trust	£945,198	19.09%
Wellcome Trust	£916,650	17.73%
CRUK	£878,761	15.91%
Gates Cambridge	£770,707	8.64%
UK Industry	£220,911	4.55%
BBSRC	£220,326	5.00%
Misc. other funders	£144,898	3.18%
UK Government	£73,542	0.45%
EPSRC	£43,238	0.91%
Grand Total	£5,361,531	100.00%

TABLE 1: Major external funding of current UOA1 PhD students

2.8.3. Monitoring and support mechanisms

UOA1 provides strong support to students throughout their studies and our PhD completion rate currently stands at 90% within four years. We are committed to continually growing and evaluating our integrated support system:

- **Colleges** of the University provide graduate students with accommodation, social space, and pastoral support from a Graduate Tutor.

- **Departments** provide a PhD supervisory team, including senior PhD coordinators. Progress is monitored regularly through meetings and associated deliverables (e.g., first-year report, which is required for registration for the PhD degree upon satisfactory performance).

- **Postgraduate School of Life Sciences (PSLS)** led by the Schools of Clinical Medicine and Biological Sciences ensures excellent supervision, support and assessment for all UOA1 graduate students, facilitating collaboration and providing core and bespoke training. The PSLS **Core Skills Training Programme** is available to all first-year students, providing foundational skills, aiding in the completion of key milestones and helping them maximise training opportunities. The PSLS also offers leadership roles through the Graduate Student and Postdoc Forum and Strategic Committee and the annual *Building Bridges in Medical Sciences* Symposium. UOA1 is committed to supporting students beyond completion, towards their future career aspirations.

- **Supporting career progression:** The PSLS **Researcher Development Programme** enables students to map their progress continually across 15 essential competencies within four interconnected areas and provides online resources for career development. Constituent UOA1 elements offer opportunities for students to present at internal seminars and annual retreats, as well as national and international conferences. UOA1 Departments also support student

applications for funding opportunities, including hosting recent graduates on a short-term basis to complete experimental work, build their publication record and consolidate plans for the next stage of their careers. With the University Careers Service, UOA1 hosts termly career seminars enabling students to explore careers beyond academia; one-to-one guidance consultations; 14 major careers events each year; an extensive programme of briefings and skill sessions; coordinated employer presentations; and a database of over 4,000 graduate-level job vacancies.

2.9. EQUALITY, DIVERSITY AND INCLUSIONS (EDI)

2.9.1. Athena Swan Silver Award

Led by Karet (Director of Organisational Affairs), the School has promoted EDI across UOA1 since REF2014. We achieved the largest departmental Athena Swan Silver Award nationally in 2013 (renewed 2016), covering all constituent elements of UOA1, focusing on: improving working culture, following the employee journey; and introducing specific actions e.g., mandating EDI training and improving communications and inclusivity. This included the 25% growth in School staff since REF 2014 (total ~3000) with all new staff fully integrated into the School's EDI structures and process.

2.9.2. Equality, Diversity and Inclusion Governance Group (EDIGG)

Established with our renewed Athena Swan Silver status, the EDIGG promotes EDI in its broadest sense, including ensuring fair processes for recruitment, funding applications and career development opportunities for all staff, including those with protected characteristics. The EDIGG oversaw the appointment of an **EDI Coordinator**, responsible for progressing the Athena Swan Action Plan and implementing EDI. They provide support for staff networks and career development and EDI and Wellbeing events to improve the working culture for all staff. They also facilitate the School's Wellbeing Programme (Section 2.4), and Staff Development and Mentoring programmes (Sections 2.3). The EDI coordinator co-chairs our equality Champion's network of >100 staff at all levels of seniority that disseminates information and embeds good EDI practice across UOA1.

2.9.3. Supporting staff with protected characteristics

UOA1 and the University supports staff with protected characteristics to conduct productive research, thereby promoting a diverse and inclusive research culture:

- **University Diversity Networks** enable staff with protected characteristics to develop communities beyond academic boundaries and encourage a sense of inclusivity. There are University- and School-level champions for Race Equality, Disability, Gender Equality and LGBTQ+. A current priority is to combat structural racism and promote the University reverse mentoring programme, where senior white academics, e.g., Maxwell, Regius Professor of Physic, are assigned BAME reverse mentors who provide direct insight into the lived experience of a person of colour as a more junior staff member in Cambridge. This has shaped the School's approach to discussing race and racism, and to supporting BAME staff. The University runs annual events for Black History Month, plus regular BAME Staff network events and an annual dinner for the BAME network attended by the Vice-Chancellor.

- **School of Clinical Medicine focus groups** for LGBTQ+ staff and those with 'invisible' disabilities/relapsing-recurring health conditions and the Academic Women's Forum (Section 2.9.4), identify issues specifically affecting diverse members of our research community and seek their advice to improve our environment.

- **Departments, Institutes and Units** each host one or more **Equality Champions** who are responsible for increasing awareness of our EDI Inclusion Programme by promoting Athena Swan and EDI matters throughout the School.

2.9.4. Promoting female leaders

The Academic Women's Forum, led by eminent female scientists, Deaton (Public Health and Primary Care), Philpott (Oncology and Head of School of the Biological Sciences) and Jorgensen (Medicine) provides educational peer support and mentoring opportunities for female research staff. It complements a UOA1-wide initiative to actively promote female leaders within our SRCs (Box 2.6).

BOX 2.6: Promoting female leaders within UOA1:

Cancer Executive Board has increased female membership from a single member in 2014 to 16 today with an overall M:F ratio of 1.25:1.

Metabolism and Endocrinology Scientific Advisory board male:female membership has evolved from a 6:1 ratio in 2014 to 5:3 today.

Targeted support also exists for female leaders, including **Daphne Jackson Fellowships** that support staff who have taken a break of two years or more from STEM research for family, caring or health reasons. Several UOA1 academics have international profiles in promoting equality, diversity and inclusion as well as mentoring. For example. Karet has run EDI and mentoring symposia in Canberra and Melbourne and spoken recently at Memorial Sloan Kettering Cancer Centre, New York to promote women succeeding in science.

2.10. FLEXIBILITY IN WORK AND LEAVE PRACTICES

2.10.1. Remote working arrangements

We support staff working flexibly and remotely. This is enabled by the School Computing Service that provides remote server support for secure and rapid access to workplace files.

Since 2017, the University has worked with the 'My Family Care' organisation to provide subsidised access to emergency childcare and a network of adult and eldercare across the country. The services offered include: emergency support to find appropriate childcare at short notice; access to school holiday clubs nationwide; and back-up domiciliary care for elderly relatives, or an adult dependant.

2.10.2. Supporting staff returning from leave

The Returning Carers' Scheme (launched in 2016, when 17 staff in the School received awards, including Dr. Pathan, University Lecturer in Paediatrics), supports academic activity and builds up the research profiles of our staff returning from a period away from work. The Scheme provides up to GBP13,000 to support attendance at UK and international conferences and training courses, and research activities including equipment purchases. In addition, the University SPACE (Supporting Parents and Carers) network provides UOA1 members with an informal point of information and points of contact for those during and returning from leave. The School also covers excess costs of maternity or paternity leave so as not to disadvantage researchers where their grant funder will not cover these costs.

3. Income, infrastructure and facilities

3.1. RESEARCH FUNDING STRATEGY

3.1.1. Overarching UOA1 funding strategy

UOA1 maintains and grows its research environment by pursuing six funding objectives aligned directly to our Research and Impact Strategy (Section 1). The 20% increase in competitive peer-reviewed funding from GBP127 million in 2014 to GBP153 million in 2019, testifies to the success of this strategy.

- ***We seek long-term strategic funding*** aligned directly with our Research and Impact Strategy.
- ***We encourage interdisciplinary awards*** enabled by our structure of SRCs and CCTs (Section 1) that unite Departments, Institutes and Units in research collaborations both within and beyond Cambridge.
- ***We practise diversity and inclusion principles as part of our funding strategy*** ensuring all staff are aware of internal and external funding opportunities, with particular emphasis on independent funding opportunities for ECRs.
- ***We practise good stewardship*** ensuring University resources are distributed fairly and managed proactively to the highest standard. We ensure industrial research is strongly supported but is not inappropriately subsidised by applying consistent minimum fEC levels.
- ***We support talented individuals to secure personal funding*** at all career stages from MB PhD studentships through to Wellcome Principal Research Fellowships and Royal Society Professorships. This support includes bridging funds at key points, mentoring from successful academics, feedback on applications, and practice interviews.
- ***We provide state-of-the-art infrastructure and platforms*** to enable the best research, providing investigators with the latest technology and research facilities.

Each constituent element within UOA1 hosts a Research Committee and an Information Resources Committee. The former considers research opportunities and collaboration among members; the latter coordinates bids to University or external funding agencies for key infrastructure and capital needs. By uniting the work of our SRCs and CCTs through our Research and Impact Strategy, we ensure funding initiatives are identified and secured with maximum impact.

3.2. MAJOR AND PRESTIGIOUS AWARDS DRIVING IMPACT

3.2.1. Consortia and prestigious grants resulting in high-quality outputs and impact

Since REF2014, UOA1 has secured 33 grants each valued >GBP5 million (total >GBP374 million) including overarching awards (Box 3.1), as well as those supporting the work of specific SRCs:

- ***SRC and CCT-specific award exemplars:***
  - ***Cancer:*** In addition to those detailed in Section 1 and 4, ***Cancer*** has secured the following major awards: **(i) CRUK Major Centre and Training Award** (2017-2022; GBP38.2 million) designated as one of only four CRUK Major Centres in the UK, this award supports >800 researchers and healthcare professionals, organised into 12 programmes across the cancer research and treatment community in Cambridge. **(ii) CRUK Cambridge Institute Core**

Award (2019-2024; GBP21.5 million) supports 26 basic and translational research groups as well as core facilities focused on understanding the biology, diagnosis and treatment of cancer. **(iii) The first CRUK Grand Challenge** (2017-2023; GBP25 million) generating a virtual reality 3D tumour at the single cell level. **(iv) MRC Cancer Unit** (2016-2021; GBP12.3 million) supporting 13 basic and translational research groups and core facilities focused on understanding the basic biology and treatment of cancer. The success of the ***Cancer*** SRC has underpinned: the announcement by Government of >GBP100 million funding to build a new 25,000m^2 Cancer Research Hospital on the Biomedical Campus (Section 1.6.1). **(v) CRUK EPSRC Cambridge Manchester cancer imaging centre** (2013-2018; GBP7.4 million) to develop doctoral training and novel imaging techniques.

- ***Cardiovascular and Respiratory:*** **(i) British Heart Foundation (BHF) Centre for Research Excellence** (renewed 2019-2024; GBP6 million) unites 32 research groups across the University, Wellcome Sanger Institute, Babraham Institute and MRC Mitochondrial Biology, Biostatistics & Epidemiology Units with a focus on cardiometabolic medicine, functional genomics (in collaboration with the ***Genetics and Genomics*** CCT and UOA2). **(ii) BHF Oxbridge Centre of Regenerative Medicine founded in 2013 and renewed in 2017** (GBP2.5 million), unites research groups in cardiovascular repair and regeneration at the Universities of Oxford, Cambridge, Bristol, Leeds and Manchester. The success of this SRC has underpinned the construction of the new Heart and Lung Research Institute located next to the new Royal Papworth Hospital (Section 1.6.1). **(iii) The Cystic Fibrosis UK Innovation Hub** (GBP5 million) encompasses clinicians and researchers at Royal Papworth Hospital and the new Heart and Lung Research Institute.

BOX 3.1: Examples of major overarching UOA1 awards:

NIHR-BRC (renewed in 2017, GBP114 million/5 years) is the largest single BRC grant in England. The strategic objectives of this award relate to early translational research and experimental medicine and its organisation is aligned purposefully with the UOA1 SRCs and CCTs.

MRC Clinical Research Capabilities and Technologies Initiative (awarded in 2014 (GBP14.6 million Stratified Medicine; GBP3.5 million under Single Cell Genomics) was deployed to develop new technologies for measuring and imaging molecules in humans, and apply these technologies to understand and treat human diseases with a particular focus on cancer and metabolic disorders.

Milner Therapeutics Institute and Consortium (active since June 2015 and based in the Jeffrey Cheah Biomedical Centre (GBP3.2 million Section 3.3.2) supports a consortium of: the University; the Wellcome Sanger and Babraham Institutes; Astex, AstraZeneca, GlaxoSmithKline, Shionogi, Pfizer, Janssen R&D and Ferring Pharmaceuticals, facilitating the rapid exchange of reagents and information for research. Each industry partner has set aside funds for collaborative projects with UOA1, of which 19 are ongoing.

- ***Infection and Immunity:*** In addition to the awards detailed in other Sections, members of this SRC have received major Wellcome Trust funding to study: **Fundamental and therapeutic insights into tuberculosis** (2014-2021; GBP6.7 million); **Complete humanisation of adaptive cellular immunity in the mouse** (2018-2023; GBP5 million); and the genetics of **primary immunodeficiency** (2020-2025; GBP4.2 million).
- ***Metabolism and Endocrinology:*** **(i) Wellcome Trust Major Award** (2018-2023; GBP5 million); **(ii) MRC Mitochondrial Biology Unit** (2017-2022; GBP19 million); **(iii) MRC Metabolic Diseases Unit** (2018-2023; GBP12 million); **(iv) Wellcome Trust Diabetes and Inflammation Laboratory** (2015-2020; GBP8.2 million).

- ***Women and Children's SRC:*** Holds **three Wellcome Investigator awards, an MRC Experimental Medicine Challenge award and ERC Advanced grant** and co-lead **INNODIA IMI2** network of 31 academic institutions, six industrial partners, an SME, and two patient organisations (Section 1.5.2., EUR50 million, GBP12 million to Cambridge).

3.3. ORGANISATIONAL INFRASTRUCTURE AND INVESTMENT

3.3.1. The Cambridge Biomedical Campus

As detailed in Section 1.3., almost all UOA1 organisational infrastructure and staff are located on the 140-acre Biomedical Campus.

3.3.2. University organisational infrastructure

UOA1 organisational infrastructure based on the Biomedical Campus includes 10 specialty Departments, six physical Institutes and three MRC Units totalling 112,250 m^2 Gross Internal Area of research space. The great majority of this space is in purpose-built buildings opened in the last 25 years. Since REF2014 we have constructed and opened several new facilities on the Campus allowing expansion of UOA1 research (Figure 3):

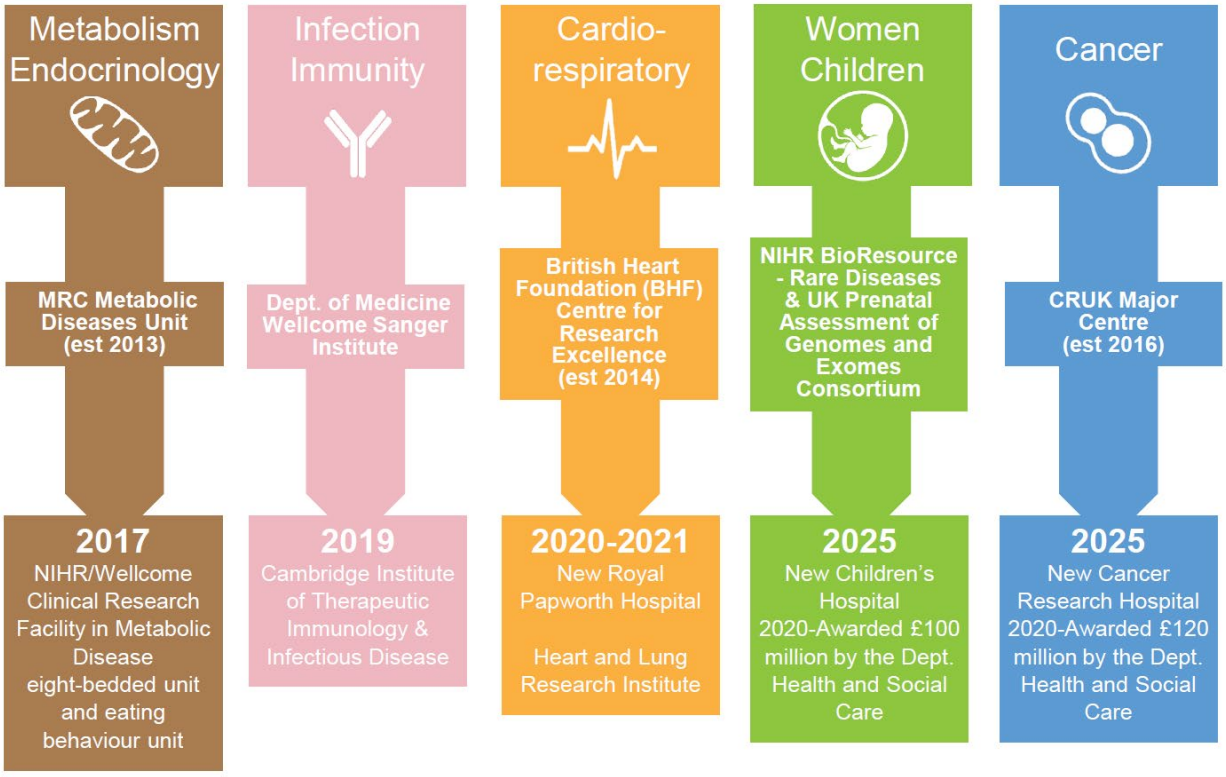

Figure 3, Strategy drives growth in infrastructure: Since REF2014, each SRC (top) has conducted world-class research using major infrastructure and competitive awards (middle) that have enabled directly securing of funds the building and planning of major new infrastructure (bottom); thereby enabling sustainability of our environment.

- **Major new infrastructure enabling basic discovery research:**
  - ***Anne McLaren Building*** (opened in 2019, GBP112 million, 21,500m^2 GIA) housing one of the largest small animal research facilities in the UK with capacity for around 22,000 individually ventilated mouse cages as well as aquatic facilities. Includes five barriered areas:

four are minimum Specific Pathogen Free (including one germ free) and one Specific and Opportunistic Pathogen Free, for breeding.

- ***Heart and Lung Research Institute*** (HLRI, to open fully in 2021, GBP65 million, 7,950m^2) funded by a strategic award from the BHF, the UK Research Partnership Investment Fund, the Royal Papworth Charity and the University. Situated next to Royal Papworth Hospital, it will provide space for >380 scientists studying genomics, population sciences, research into cellular mechanisms of disease and translational science. To promote translational initiatives it includes a special ten bed facility for first-in-patient studies.
- ***Jeffery Cheah Biomedical Centre*** (opened 2019, GBP94 million, 18,000m^2) housing:
  - ***Cambridge Institute of Therapeutic Immunology and Infectious Disease (CITIID)*** funded by a GBP25 million competitive grant from HEFCE, a major philanthropic donation, and the Wolfson Foundation. It houses the UK's largest academic microbiological Containment Level 3 facility and unites >30 research groups in infectious disease and immunity research including autoimmune disease, cellular immunology and inflammatory disease with associated strengths in genomics and genetics – driving COVID-19 research on the Biomedical Campus (www.citiid.cam.ac.uk).
  - ***Wellcome-MRC Cambridge Stem Cell Institute (CSCI)*** comprises the largest critical mass of interdisciplinary stem cell researchers in any single institution in Europe. Housing 27 research groups studying the normal and disease biology of stem cells and their role in treatment. Forty percent of principal investigators are clinician scientists facilitating synergistic interactions between basic and disease-focused research. Through the NIHR-BRC the institute facilitates inter-disciplinary stem cell research across a network of >700 stem cell researchers in the University. It also contains an expanded GMP Cambridge Cellular Therapy Laboratory.
  - ***Milner Therapeutics Institute*** provide collaborative laboratory space co-locating UOA1 and industry researchers across a global community of 80 affiliated organisations with expertise in therapeutic development including the national CRUK-AstraZeneca Functional Genomics Facility.

- **Major new infrastructure enabling clinical translation:**
  - ***New Royal Papworth Hospital*** opened in 2019 on the Biomedical Campus, This GBP200 million new hospital is the UK's leading heart and lung transplant hospital (discussed fully in Section 3.3.2). Government funding for two additional major research and treatment facilities to be built on the Biomedical Campus, the Cambridge Cancer Research and Children's Hospitals, was also recently announced (see Section 1.6.1).
  - ***NIHR/Wellcome Trust Clinical Research Facility*** (GBP19.5M, 6000m^2, opened in 2017) embedded within Cambridge University Hospital, includes:
    - ***Clinical Research Facility in Metabolic Disease*** (4,000m^2) supporting complex, high-intensity metabolic studies within an eight-bedded unit and an Eating Behaviour Unit.
    - ***Interventional Procedures Unit*** (2,000m^2)**:** eight-bed unit, two procedure rooms and dark room for *ex vivo* imaging and specimen handling or experimental endoscopic imaging studies e.g. multispectral and molecular imaging for early detection of cancer. This facility was instrumental in developing Impact Case Studies from ***Cancer*** and ***Metabolism and Endocrinology***.
  - ***NHS Blood and Transplant (NHSBT) Research Units:*** serve as the hub for many UOA1 collaborations and houses multiple UOA staff with honorary clinical contracts e.g., Mendez-Ferrer and Ghevaert (Cambridge Stem Cell Institute) work in the NHSBT contributing to its 2015-2020 R&D strategy, including development of novel blood cell therapies. Ghevaert serves also as a consultant haematologist in the NHSBT and is developing the next generation of stem cell-based therapies for treating haematological disorders with two trials in late planning.

- **Specialist infrastructure for basic and translational research:** UOA1 facilities across the Biomedical Campus are well supported for analysing molecules, cells and tissues. Exemplars include, but are not restricted to:

  - ***Molecules:*** The quantification of DNA, RNA and protein at genome-scale underpins the work of all SRCs and is coordinated through the ***Genetics and Genomics*** and ***Mechanism of Disease*** CCTs (Section 1.2). For example, the **Metabolic Network** links groups performing metabolomic analysis across the campus (e.g., in the MRC Cancer, Mitochondrial Biology and Metabolic Sciences Units), sharing best practice, new techniques and avoiding duplication of major infrastructure. This Network provides continually updated on-line information about access to available metabolomics and lipidomics. The ***NIHR Clinical Biochemistry Assay Lab (CBAL)*** established in 2008 with support from the NIHR Cambridge BRC, performs >500 different biochemistry tests–particularly immunoassays–issuing >1.2 million tests/year. The lab serves UOA1 research as well as studies in other BRC sites around the UK. Analytical work performed by CBAL has been presented in hundreds of scientific papers published in high-ranking journals. A recent on-line poll of CBAL service users gave the laboratory a 98% approval rating. UOA1 investigators are also well served with DNA and RNA sequencing facilities. The ***CRUK Cambridge Institute Genomics Core Facility*** is accessible to investigators studying cancer across UOA1, providing extensive library preparation, Illumina sequencing and single cell sequencing. The ***Human Cell Atlas spatial transcriptomics*** core laboratory provides large area spatial transcriptomics (LaST) quantitative gene mapping a variety of human tissues (e.g., placenta, liver, brain). The ***East Midlands and East of England Genome Laboratory Hub*** serves as our key translational sequencing facility. Structural biology expertise is a key element of the ***Mechanism of Disease*** CCT, and UOA1 researchers drove the Wellcome Trust-supported establishment of Cryo-Electron Microscopy infrastructure within the University of Cambridge.
  - ***Cells and tissues:*** Several constituent UOA1 facilities house state-of-the-art cell isolation and imaging facilities including confocal and two photon microscopes with fluorescence correlation spectroscopy capability; high-throughput, high-content microscopy; multi-point time-lapse live cell imaging; optogenetics platforms; electron microscopy; as well as high-end cell phenotyping accessible to all UOA1 researchers (Box 3.2).

BOX 3.2: NIHR BRC Cell Phenotyping Hub:

Situated in the heart of the Biomedical Campus, providing cell sorting, analysis, imaging, and phenotyping expertise. Since REF2014 activity has grown dramatically: sorting hours have ~doubled to 3,300 hrs per year and annual content analysis screening and phenotyping tests increased by >1,000/year since REF2014. The Hub now serves 50 research groups drawn from all SRCs, nine of our 10 Departments, and all Institutes and Units.

The Hub fosters collaborations regional, national and international collaborations. For example, together with the National University of Singapore (SGD$8 million) the Hub has standardised comparison of immune responsiveness in a range of clinical studies in different ethnic populations.

The Hub has remained open during the COVID-19 pandemic, providing invaluable support to major nationally significant COVID-19 studies through multi-dimensional phenotyping of >250 patients and controls at over 700 time points.

  - ***Clinical and translational research imaging:*** UOA1 benefits from the excellent clinical imaging facilities and expertise on the Biomedical Campus as well expertise at the Cavendish Laboratory, Department of Engineering, Department of Mathematics, Department of Astronomy and Department of Veterinary Medicine. We recently opened state-of-the-art

preclinical imaging facilities in the new Anne McLaren Building, as well as a new large animal facility at West Cambridge. **Preclinical imaging facilities** including PET/CT, MRI (3T, 7T and 9.4T for small animal and 3T for large animal imaging), ultrasound, bioluminescence, fluorescence, and multiphoton imaging, as well as novel imaging tools such as hyperpolarized carbon-13 MRI, deuterium metabolic imaging and optoacoustic imaging. **Dedicated GMP radiochemistry and radiopharmacy** units, with a cyclotron capable of producing the key radioisotopes (^{11}C and ^{18}F) at high radioactivities regulated and accredited by the MHRA with one of the largest portfolios of clinical PET radiotracers at an academic centre in the UK, and a dedicated non-GMP facility for the discovery and development of novel PET radiotracers. **Advanced multimodal metabolic imaging with 3T PET/MR, clinical hyperpolarizer facilities (GE SPINLab)** and a unique ^{13}C pharmacy offering the capability for combined PET/MR metabolic imaging studies with hyperpolarized ^{13}C-labelled MR and PET radioisotope-labelled substrates. The adjacent ultra-high field 7T MRI allows for ultra high-resolution imaging and spectroscopic studies including ^{2}H-labelled substrates. **Clinical MRI facilities including dedicated research on a 7T and two 3T MRIs (plus a further two 3Ts in UOA4).** In addition, the NHS will upgrade their MRI unit in 2021 with GBP4 million to house two additional 3T and four 1.5T MRIs. **The radiomics, radiogenomics and quantitative imaging groups** integrate complex information to understand mechanisms of disease and predict response and together with **AI and deep learning imaging** research collaborations with Departments of Physics and Mathematics. A databridge allows transfer of NHS images to the High Performance Computing Centre linking to the anonymised hospital EPIC data.

- ***Other key infrastructure*:** The Biomedical Campus is also the principal location of UOA2 and UOA4 researchers, providing access to epidemiological, public health and behavioural science, neurosciences and mental health expertise. Since REF2014, the MRC Units have become fully embedded within UOA1, increasing our research capacity, breadth and strength. Close to the Biomedical Campus are a wide range of University researchers with whom we collaborate (e.g., Chemistry, Engineering, Computer Sciences, Maths, Physics) and major national biomedical institutes with whom we have strategic partnerships (e.g. the Wellcome Sanger Institute and EMBL-European Bioinformatics Institute at Hinxton).

3.3.3. Specialist biobanks

UOA1 maintains a series of specialist tissue collections that underpin key research projects, including:

- **Cambridge University Hospital NHS Trust Tissue Bank** holds the Human Tissue Authority Licences (12315 and 12318) and processes the great majority of human tissues employed by UOA1 researchers. This bank has collected and curated 95,855 frozen samples and 55,434 formalin-fixed paraffin embedded tissue blocks.

- **NIHR BioResource Cambridge** of 17,500 volunteers, both with and without health conditions, who have provided DNA and consented to join research studies investigating the links between genes, the environment, health and disease. Since 2014 the BioResource has enabled over 60 studies examining the links between specific genotypes, and aspects of phenotype both in health and disease.

- **The Cambridge Biorepository for Translational Medicine** provides access to annotated fresh human tissue from organ donors. Since REF2014 it has enabled a wide range of studies across UOA1 including organoid generation, single cell analyses of haematopoietic and renal

development, mutational analyses to understand the earliest stages of cancer development and extensive contributions to the Human Cell Atlas.

- **SRC specific collections:** UOA1 is also custodian of discipline specific collections. For example, ***Cancer*** hosts the Cambridge Breast Cancer Collection of over 20,000 tumour samples. This collection has served as the basis of the Precision Breast Cancer Programme that is working with Illumina to integrate whole genome sequencing, RNA sequencing and liquid biopsies into standard of care for all women and men with breast cancer treated at Cambridge University Hospital. The Blood Stem Cell Bank includes >15,000 samples from patients with haematological malignancies and normal individuals, including cord blood and 2,600 normal control samples. The ***Women and Children's*** hosts a biobank of ~250,000 aliquots of samples (serum, plasma, tissue and nucleic acid) maintained by a team of technicians generating multiple major outputs in leading journals and served as the basis of collaborations with industry e.g., Roche Diagnostics & Illumina, and SMEs e.g., Metabolon & Sera Prognostics.

3.3.4. Industrial partner infrastructure important for UOA1 translation and impact

The Biomedical Campus and nearby locations are home to a wealth of large biopharmaceutical companies and other life science industry partners that are instrumental in our delivery of impact, including:

- **AstraZeneca (Section 1.3):** AstraZeneca's new R&D Global Headquarters (opening 2021) will become the company's largest R&D centre for oncology research as well as cardiovascular, metabolic, respiratory, inflammatory and autoimmune disease research; thereby aligning directly with our UOA1 SRCs.

- **GlaxoSmithKline:** Cambridge University Hospital houses GlaxoSmithKline's only embedded clinical unit (established 1999). This MHRA-accredited Phase I trials unit conducts experimental medicine studies, and collaborates with our Wellcome-NIHR Clinical Research Facility (Section 3.3.2). GlaxoSmithKline's major UK research laboratories are located at Stevenage, within 25 miles of the Biomedical Campus.

- **Abcam:** founded as a University spinout in 1998, now selling over 100,000 products in 140 countries and is capitalised at GBP3.5 billion. It opened its purpose built GBP46 million, 10,000 m^2 research laboratories and global headquarters on the Biomedical Campus in 2019.

- **Illumina:** the market leader in next generation sequencing, based on its acquisition of the Cambridge spinout Solexa in 2007. Its major European research site is at Granta Park, six miles from the Biomedical Campus. Collaborative programmes include the Next Generation Children's project and Personalised Breast Cancer Programme as part of Integrated Cancer Medicine (Section 1.5.2).

- **Major life science campuses** within six miles of the Biomedical Campus collaborate with UOA1 researchers, including: Babraham Campus (a community of over 2,000 people in >60 commercial life science organisations including those linked to the University e.g., Mission, Storm, Bicycle, Inviata, Phoremost, Bitbio, Kymab); Cambridge Science Park (7,250 employees in 1.9 million m2 of buildings housing 130 companies e.g., Astex, Bayer, Mogrify, Napp); and Wellcome Genome Campus (Sanger Institute, EMBL-EBI, BioData Innovation Centre and Genomics England).

3.4. UOA1-WIDE OPERATIONAL AND SCHOLARLY INFRASTRUCTURE AND INVESTMENT

3.4.1. Support for research administration

- ***Research Operations Office (ROO)*** is the University's official signatory for research grants and contracts with authority to submit, accept and negotiate grants. Each UOA1 Department, Institute and Unit has a ROO-based advisor and access to contract managers. The ROO provides expert advice in audit and compliance management, operational policy development, equipment sharing and outputs coordination, and staff training including X5 support. The pre-award service established in 2019 provides UOA1 researchers with intelligence on potential sources of funding, and facilitates interactions with industry and cross-departmental collaborations. In 2020 the ROO negotiated the consortium agreement for the Cambridge-led Covid-19 genomics consortium (COG-UK) involving multiple NHS organisations, the four Public Health Agencies of the UK, and over twelve academic partners providing sequencing and analysis capacity.

- ***School Research Governance Team*** provides specialist knowledge on research and information governance for compliance in sharing and storing of human tissue and data. The team manages the Clinical School Secure Data Hosting Service (NHS Toolkit and ISO27001 accredited) enabling UOA1 members to access patient data from partner NHS Trusts, NHS Digital, ONS and Public Health England: for example, advising the ***Women and Children's*** SRC Pregnancy Outcome Prediction Study that is seeking to understand how health in the womb influences later health outcomes by linking information routinely collected by national agencies.

3.4.2. Support for translating research to impact

- ***Office for Translational Research:*** supports UOA1 researchers to translate their discoveries towards clinical application through: seminars to increase awareness of the potential for translation; obtaining and managing seed funding (e.g., the MRC Confidence in Concept fund); major translational applications (e.g., MRC Developmental Pathway Funding Scheme); project management and partnerships with a wide range of industrial partners. It works seamlessly with Cambridge Enterprise, the University's Technology Transfer office.

- ***Research Initiatives Manager:*** supports UOA1 with strategic project management. A key role is to identify and develop collaborations across academia, affiliated NHS organisations and industry to generate additional revenue, an approach which provided support for successful applications to the Research Partnership Infrastructure Fund for funding for the Cambridge Institute of Therapeutic Immunology and Infectious Disease, and for the Heart and Lung Research Institute.

- ***Cambridge Clinical Trials Unit (CTU):*** Critical to our ***Clinical Trials*** CCT (Section 1.2) this Unit unites experts to design high quality, efficient, early phase and experimental medicine studies thereby maximising UOA1 clinical impact.
  - **Study Design:** supports novel (e.g. adaptive) efficient trial design; randomisation; statistical, health economic evaluation, analysis and reporting; trial steering and data management committee oversight.
  - **Quality Management** maximises trial quality and compliance with QA and QC; monitoring and audit**;** pharmacovigilance**; r**egulatory (MHRA/HRA) expertise, minimising delays.
  - **Project Management/Trial coordination** of multi-centre, national and international trials**;** trial initiation, site set-up and site management; Investigational Medicinal Product and sample management.

- **Data Management/IT**: Designing of case report forms and databases; data management plans; programming; data curation and quality control; management of case report forms (CRFs) and questionnaires; web-pages and portals; applications for patient self-reported – outcomes.

3.4.3. Support for information technology and data handling

State-of-the-art computational, secure data transfer, and information storage infrastructure is critical for UOA1 research. Since REF2014 the University has made major investments in energy efficient, resilient high-performance computing and data storage:

- ***Research Computing Services:*** Built in 2015 (GBP20 million), the West Cambridge Data Centre is the central hub for all University research computing. This petascale supercomputing facility provides UOA1 with the space, power, cooling and high-level security required for research computing, accessed through the 'Clinical Cloud'. In 2017, Peta4 achieved 1,696.7 PFlops, making it the fastest academic high-performance computer system in the UK.

- ***Clinical School Computing Service:*** provides IT support services to UOA1 including a private fibre Granta Backbone Network connecting all UOA1 facilities. This is being extended to the Wellcome Genome Campus (home of the Wellcome Sanger Institute and EMBL-European Bioinformatics Institute) and world-renowned MRC Laboratory of Molecular Biology. UOA1 has a dedicated secure storage area for personal identifiable and sensitive research data that complies with the NHS Digital Data Security and Protection Toolkit (‘Standards Met’) and has ISO 27001 Certification, allowing acquisition of data from NHS Digital and Public Health England.

3.4.4. Scholarly infrastructure

The Office of Scholarly Communication (OSC) within the Library supports the University’s commitment to disseminating its research and scholarship as widely as possible to contribute to society as well as to academic advancement. The University’s Open Access Policy sets out the framework for ensuring that publications authored by University researchers, staff and students are made open access, where applicable. To this end, the OSC provides UOA1 with administrative and infrastructure support as a stable repository service to share research outputs and data openly.

3.5. BENEFITS IN KIND AND FUNDING FROM NIHR

UOA1 has secured GBP3.3 million of benefits in kind in access to national facilities (Research England) and a total of GBP207 million from NIHR.

3.5.1. Seminars and workshops

Each SRC within UOA1 benefits from externally sponsored symposia and/or seminar series. For example, ***Cancer*** holds an annual symposium sponsored jointly by AstraZeneca and the CRUK Major Centre. Attended by over 300 delegates in both 2017 and virtually (due to COVID-19 restrictions) in 2020, this two day meeting unites UOA1 researchers with industry scientists to plan and develop new collaborative research cancer clinical trials.

3.5.2. Access to specialist resources and equipment

The ***Cancer*** and ***Mechanisms of Disease CCT*** via the Department of Haematology has close relations with the Wellcome Sanger Institute providing access to sequencing. Through membership of a Block Allocation Group, members of these UOA1 components also have free access to cryo-electron microscope beamtime at the eBIC facility at Diamond Light Source as well as access to

cryo-electron microscope beamtime provided by Thermo Fisher as part of the Cambridge Pharmaceutical Cryo-EM Consortium. Roche and GE healthcare have loaned the ***Imaging CCT*** three automated breast Ultrasound machines, a mammography machine, a clinical research scientist, funding for support staff and studentships and research support for machine time; GlaxoSmithKline funded a clinical scientist, PhD studentships. The INNODIA consortium provides the ***Metabolism and Endocrinology*** and ***Women and Children's SRCs*** with access to over EUR10 million in in-kind contributions from industry and the EU each year. Diabetes technology research has received discounted or donated equipment as well as access to proprietary information to carry out world leading research.

3.5.3. Sponsored academic positions

UOA1 collaboration with our NHS partners is critical to our Research and Impact Strategy. Cambridge University NHS Foundation Trust currently funds 72.2FTEs clinically practising scientists within UOA1, including Professors (14), Readers (6), Senior Lectures (2), Lecturers (41) as well as other clinical posts. An additional 14.6FTEs are supported by the Clinical Academic Reserve fund (a partnership of CCGs across the Eastern Region) including the Clinical Dean as well as 12 Professors and two Readers.

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

4.1. COLLABORATION, NETWORK AND PARTNERSHIP SUPPORT

4.1.1. Overarching support of collaboration

Collaborative research lies at the heart of our Impact (Section 1), Staffing (Section 2) and Income and Infrastructure Strategies (Section 3) and benefits greatly from the co-location of almost all UOA1 staff on the Biomedical Campus. The organisational structure of UOA1, comprising five SRCs and five CCTs, further promotes the formation of large multidisciplinary teams. As detailed in prior Sections, collaboration with industry is enhanced by the appointment of senior leaders of our major industrial partners to key UOA1 governance boards (Box 2.2), the co-design and occupancy of major UOA1 infrastructure with industry (Section 2.6.4), and co-recruitment, mentoring and training of staff with industry partners. In addition to these mechanisms, UOA1 benefits from three overarching systems of support that facilitate, initiate, and maintain collaborations:

Cambridge University Health Partners (CUHP) is a private company limited by guarantee, established and designated as an Academic Health Science Centre (AHSC) in 2009 (redesignated 2020-2025). The Chairs and Chief Executives of Cambridge University and Royal Papworth Hospitals NHS Foundation Trusts, the Vice-Chancellor of the University, Pro-Vice-Chancellor for Enterprise and Business Relations and Regius Professor of Physic all sit on the CUHP Board which is chaired by Laurel Powers-Freeling, a businesswoman with many senior multinational advisory positions. Since REF2014, CUHP has facilitated the attraction of industry partners and associated infrastructure to the Biomedical Campus that now serve as hubs for numerous collaborations.

University funded Strategic Research Initiatives (SRIs) and Interdisciplinary Research Centres (IRCs) unite expertise from across the University to address large-scale multi-disciplinary research challenges. SRIs are initiated with University funding (GBP55,000/year) and graduate to IRCs (GBP60,000/year) after six years if proven to be effective collaborative networks. UOA1 hosts (Cambridge Academy of Therapeutic Sciences, Reproduction, Immunology and Metabolism) and four of 12 IRCs (Cancer, Cardiovascular, Infectious Disease, and Stem Cells) aligned directly with our SRCs.

Other collaboration vehicles include partnerships with the Association of British HealthTech Industries, Birmingham Health Partners, Leeds City Region and Health Innovation Manchester focused on strengthening national pathways for healthtech innovation.

4.2 EVIDENCE OF AN EFFECTIVE COLLABORATION STRATEGY

4.2.1. Sustainability through regional and national academic collaborations

The UOA1 environment described throughout this statement has proved central to establishing, sustaining and growing regional, national and international collaborations. These initiatives include vehicles that facilitate research across UOA1 (Box 4.1), as well as those specific to individual SRCs.

Exemplar SRC-specific collaboration vehicles:

- **Cancer:** In 2015, Cambridge was the first of two **CRUK Major Cancer Centres** established in the UK with an award of GBP35 million (see also Sections 2.6.2, and 3.2.1). This UOA1-led matrix organisation of 12 Programmes has grown from an initial membership of 300 to >800 University staff, engaging multiple UOAs, NHS and industry partners. Between 2018-2019, the CRUK Cambridge Major Centre published >800 primary collaborative papers and from April to October 2018 enrolled >1,100 patients, on observational (>780), interventional (>260), and

observational/interventional (>60) clinical trials. Work from the CRUK Major Centre underpins five of our Impact Case Studies (Section 1). The strength of collaborative culture in the Centre has also led to further, large-scale partnerships (Sections 1 and 3). For example, in 2018 ***Cancer*** founded the **Mark Foundation for Integrated Cancer Medicine** with GBP9 million grant that is deploying machine learning to integrate imaging, digital pathology and genomics data in real-time, transforming the way the world treats cancer (Section 1.5.2). This initiative has established collaborations across 14 University departments spanning UOA1, 2, 9-11, as well as the Wellcome Sanger Institute and MRC Laboratory of Molecular Biology. The Institute has also established direct collaboration with industry including: (i) **AstraZeneca** enabling testing of new therapies in prospective clinical trials with GBP6 million of industry support; (ii) **Microsoft Research** (Image texture analysis); (iii) **GE Healthcare** (Imaging); (iv) and **AACR GENIE** (genomics). The CRUK Cambridge Major Centre has successfully competed for >GBP26 million in further collaborative funding including the **CRUK Children's Brain Tumour Centre of Excellence** (Section 1.6.1), **CRUK-International Alliance for Cancer Early Detection**, and **Krishnan-Ang Foundation Award** (Section 1.5.2).

BOX 4.1: Collaborative research vehicles

Cambridge NIHR-BR: the country's largest single BRC award, unites our category A UOA1 and C NHS employees conducting clinical research, as well as colleagues in UOA2 and 4. It includes the NIHR BioResource for Translational Research in Common and Rare Diseases (Section 3.3.3) and NIHR Clinical Research Facility for Experimental Medicine that is a key component of our Clinical Trials CCT (Section 1.2).

NIHR Clinical Research Network (CRN) Eastern and Eastern Academic Health Science Network (EAHSN): In 2018-19, Cambridge University Hospital was England's top-performing Trust for increasing CRN supported studies. Through the NHS and Office for Life Sciences-funded EAHSN we collaborate with academia, citizens, health services and industry to realise the value of innovations more quickly, e.g., creating a highly effective testing infrastructure across a population of 5.5 million people to implement and evaluate the 'Cytosponge' reported in one of our Impact Case Studies (Section 1.5.3).

100,000 Genomes Project: UOA1 provides leadership to five GeCIP domains that align with our SRCs and CCTs (Endocrine and metabolism; Inherited cancer predisposition; Non-malignant haematological and haemostasis disorders; Head and neck cancer; Ovarian and endometrial cancer). This includes the development of algorithms to analyse whole genome sequencing to identify cancer patients for targeted therapies and families with high cancer risk, now deployed in the Genomics England bioinformatic domain.

- ***Cardiovascular and Respiratory:*** In 2013 (renewed 2017), founded the British Heart Foundation Oxbridge Centre for Regenerative Medicine together with the Universities of Oxford and Bristol. The Centre unites world-leading research groups with expertise in cardiovascular repair, regeneration (Oxford), and wound healing (Bristol), with major focus on stem cells and genetics in the context of regeneration (Cambridge). Also founded the GBP6 million British Heart Foundation Centre for Cardiovascular Research Excellence, uniting 32 world-leading research groups across the University, Wellcome Sanger Institute, Babraham Institute and MRC Mitochondrial Biology, Biostatistics & Epidemiology Units studying population and data sciences and genomics of cardiorespiratory disease.

- ***Metabolism and Endocrinology:*** Together with scientists from the Women ***and Children's*** SRC, ***Metabolism and Endocrinology*** leads INNODIA, an IMI2 global partnership (Section 1.5.2). Vidal-Puig leads components of two EU Horizon research programmes, EPOS and LITMUS, studying non-alcoholic fatty liver disease. Cambridge led the Rare Diseases and

Obesity Groups of the Wellcome Trust funded UK10K programme, one of the world's first large scale exome sequencing programmes. O'Rahilly chairs Genomics England's Clinical Interpretation Partnership in rare Endocrine and Metabolic Diseases co-ordinating UK wide research activity focusing on these disease areas.

- ***Women and Children's:*** The Centre for Trophoblast Research (founded 2007, GBP10 million donation; Section 2.6.2) drives multiple collaborations across UOA2,5,8 and 12 and the Babraham and the Wellcome Trust Sanger Institutes. Since REF2014, these collaborations have yielded >GBP4 million in grant income and >50 publications. Collaborations among the Departments of Paediatrics, Medical Genetics, the NIHR Rare BioResource and Illumina have demonstrated the utility of whole genome sequencing for rapid diagnosis of rare/serious genetics diseases in children. The Next Generation Children's Project has demonstrated benefit to intensively ill children, which supported the nationwide launch of whole exome sequencing in sick neonates of unknown cause in Oct 2018.

4.2.2. Sustainability through international academic collaborations (see also Section 2.6.2)

- ***Cancer*** is a founding member of the **Cancer Core Europe Consortium** (CCEC, established 2014). CCEC comprises seven of Europe's leading cancer institutions: CRUK Cambridge Major Centre; German Cancer Research Center; Gustave Roussy, France; Istituto Nazionale dei Tumori di Milano, Italy; Karolinska Institutet, Sweden; Netherlands Cancer Institute; and Vall d'Hebron Institute of Oncology, Spain. Each year the CCEC treats 60,000 newly diagnosed cancer patients, delivers 300,000 cancer treatments and hosts 1 million outpatient visits. More than 1,500 clinical trials are being conducted across the seven cancer centres e.g., Basket of Basket trial (GBP1.7 million AstraZeneca award 2017). CCEC also provided important European responses to the COVID-19 pandemic (van de Haar et al., *Nature Medicine* 2020). In 2020 the CRUK Cambridge Major Centre was named an **AstraZeneca Partner of Choice** joining a cadre of leading Cancer Centres in the US and Europe to promote academic-industry collaborations in drug discovery. Other large international collaborations include the **CRUK Alliance for Cancer Early Detection** (Section 1.5.2) and the **CRUK Children's Brain Tumour Centre of Excellence** (Section 1.6.1.).

- ***Cardiovascular and Respiratory:*** has established large international partnerships e.g., EU Horizon 2020 EUR6.5 million **RITA-2 trial** of rituximab in myocardial infarction, a collaboration across nine European countries and the I**nternational Consortium for Genetic Studies in Pulmonary Arterial Hypertension** (www.pahicon.com), encompassing 30 centres from 14 countries.

- ***Infection and Immunity*** founded the **Cambridge-Africa Programme** (Section 1.5.2). **The European Vasculitis Society** (EUVAS) engages 150 experts from 20 countries, with contributing leadership from UOA1. EUVAS has inspired founding of similar groups in Australia-New Zealand, Japan and North America and the **European Vasculitis Genetics Consortium** that conducted the first GWAS studies in Vasculitis (Lyons *NEJM* 2012, *Nat Comms* 2019).

- ***Metabolism and Endocrinology:*** The UOA1-invented closed-loop glucose control system has led to leadership roles in several international consortia (**Dan05, APCam11, CLOuD, KidsAP**) involving academic partners based in the UK (9 sites), EU (7 sites) and USA (8 sites). Funded by a total of GBP15 million in grants in collaboration with industry partners Medtronic, Abbott and Dexcom, these studies have contributed to the societal, regulatory and policy acceptance of the artificial pancreas as the leading therapy option in children and adults with type 1 diabetes.

- ***Women and Children's:*** co-lead **The COnsortium of METabolomics Studies** (COMETS), an international partnership of prospective metabolomic cohort studies, and is a member of the **Global Pregnancy Collaboration** (CoLab), facilitating harmonised perinatal data management and collaborative research. Members have longstanding collaborate research projects across the world e.g., with Centres in Uganda, The Gambia, South Africa and the USA. Rowitch is a visiting Professor at Hong Kong University where he advises on genomics medicine policy, and an adjunct Professor at UCSF and co-director of an NIH funded study of cellular and genetic pathways of early human brain development.

4.2.3. Sustainability through industry collaborations

The Biomedical Campus that houses almost all UOA1 staff is a UK Government Life Sciences Opportunity Zone, the largest centre of life sciences and medical research in Europe, and the largest employment site in Cambridge. Cambridge University Health Partners oversaw a release of 70 acres from the greenbelt (2009), attracting major industry collaborators including AstraZeneca (see Section 1.3). A further 40-acre expansion to 30,000 academics, clinicians and industry researchers is planned by 2030. The **GlaxoSmithKline Cambridge Alliance** has supported 120 projects, leveraging GBP30 million toward UOA1 research; e.g., Göttgens and Laurenti (Cambridge Stem Cell Institute) and GlaxoSmithKline are using single cell sequencing to develop gene therapy products. The **AstraZeneca global R&D** headquarters is opening in 2021 (Section 1.3), and >2,500 of their staff who have been based in Cambridge for over two years are already engaging in collaborative research projects with UOA1 partners, most notably ***Cancer*** (Section 4.2.1). UOA1 was also a founding UK site in **Pfizer's Innovative Target Exploration Network** focused on deubiquitinylation enzymes with potential in cancer, autoimmune, cardio-metabolic. **Abcam** is a further GBP3.5 billion Cambridge spinout which has re-located their headquarters to the Biomedical Campus.

4.3. CONTRIBUTIONS TO THE ECONOMY

4.3.1. Overarching contributions to the economy

The Biomedical Campus is a key component of the Cambridge life sciences cluster, that has an annual cluster gross value added (GVA) of GBP2.9 billion (Development Economics report commissioned by AstraZeneca). UOA1 is also a major contributor to our local entrepreneurial environment that has the highest patent rate in the UK (316 per 100,000 residents) and 5,100 registered knowledge-intensive companies, generating GBP18 billion in revenue. Life science and healthcare company turnover in the Cambridge area grew by 14.7%, and employment numbers by 5.9%, from 2011-2018 (University Centre for Business Research annual surveys). The Development Economics Report estimated that cluster growth will generate an additional GBP2 billion annual GVA by 2032**.** Together with local authorities and the Department for International Trade, Cambridge University Health Partners hosted 26 events with >900 attendees and >120 international companies drawn from 24 countries e.g., Texas Medical Center and the Science & Technology Commission of Shanghai Municipality (2018-19).

4.3.2. UOA1-driven investment in start-up companies

The Biomedical Campus-based UKRI University Enterprise Zone links UOA1 staff to computing, engineering and manufacturing in West Cambridge, promoting access for start-ups to expertise at subject interfaces and driving applications in therapeutics, medtech and digital health.

Cambridge University Health Partners optimises pathways from invention to company creation and growth and Cambridge Enterprise provides funding and intellectual property support at early stages, critically underpinning our impact (Box 4.2). Between 2013-2017, University spin-outs raised USD2.2 billion in capital, leading Universities globally. In the same period, Cambridge spin-outs closed 96 deals, second only to Stanford University in total number of deals (Global University Venturing;

examples Box 4.2). NHS invention by UOA1 is supported by Health Enterprise East, an NHS seed fund and technology transfer service.

Sources of entrepreneurial advice, resources and facilities for UOA1 start-ups include: Cambridge Innovation Capital (University preferred investor, which has raised GBP275 million to date), the vibrant Cambridge Venture Capital ecosystem (GBP1.1 billion funds raised in the past two years); Start Codon, part-funded by Genentech and angel funding networks, including Cambridge Angels (Box 4.2).

BOX 4.2: UOA1 Impact through Cambridge Enterprise (CE) supported start-up companies:

Inivata: Invented InVisionFirst™-Lung Liquid Biopsy (IF-LLB) to detect non small cell lung cancer-derived mutant DNA in the blood. Supported by CE and Cambridge Innovation Capital seed funds yielding >GBP75 million in funds. Employs 60 staff in the UK and the US. IF-LLB is approved in the US (Impact Case Study Rosenfeld et al.).

Morphogen-IX: Developing new treatments of pulmonary arterial hypertension (PAH) supported by CE and GBP19.8 million seed funds alongside venture capital company Medicxi. (Impact Case Study Morrell et al.)

Cambridge Gene Therapy: Developing new gene therapies of lysosomal storage diseases. Founded with seed funding from CE (Impact Case Cox Morrell et al.)

Apcintex: CE supported UOA1 to protect haemophilia treatments and licence to University spin-out ApcinteX in 2014. GBP14 million series A seed funds invested alongside Medicxi and IP Group. Phase I/II clinical trial began in October 2019.

Z Factor: Founded in 2015 by UOA1 with the support of CE to develop new treatments of alpha-1-antitrypsin (A1AT) deficiency. In 2016 a GBP7 million Series A investment was joined by Cambridge Innovation Capital. The first healthy human volunteer (HV) was dosed in August 2020.

Bilitech: Developing new stem cell approaches to repair and replace diseased organs, beginning with damaged or diseased bile duct. Since 2017, CE supported IP development and provided seed funding.

Exvastat: Founded in 2016 to repurpose treatments for acute respiratory distress syndrome, receiving GBP1.6 million investment from Cambridge Innovation Capital. Phase Ib study in healthy subjects completed in 2018. 2020, EUR3.6 million grant awarded through to test treatment in patients with severe COVID-19.

4.3.3. UOA1-driven economic benefits through workforce education

The Cambridge Judge Business School runs educational programmes to support commercialisation, including the Accelerate Cambridge programme that has trained over 400 entrepreneurs, helped 170 business ventures, and raised >GBP100 million in capital since 2012. Leveraging our sponsorship of the University Technical College and partnership with Anglia Ruskin University, we deploy apprenticeships to build a talent pipeline for the Biomedical Campus. We have enabled over 200 nursing and healthcare science apprenticeships, and continue to support STEM initiatives to widen participation.

4.4. CONTRIBUTIONS TO SOCIETY

4.4.1. UOA1 impact on policy and healthcare guidelines

To ensure our research informs policy and is translated efficiently and effectively into impact, the University's Centre for Science and Policy and the recently established Bennett Institute provide UOA1 staff with professional services, workshops and connections with policy-makers. Many UOA1 staff Chair and/or serve on key government, professional and other stakeholder bodies that generate policy and healthcare guidelines, well-illustrated by our Impact Case Studies:

- ***Cancer:*** de-escalated therapy for patients with breast cancer, underpinning National Institute of Clinical Excellence (NICE) and UK Royal College of Radiologist recommendations of less toxic, partial-breast radiotherapy with projected NHS healthcare savings of GBP42 million/year (**Coles and Earl Impact Case Study**). The national ASTER study resulted in NICE recommending endosonography instead of surgical mediastinoscopy to stage lung cancer, thereby decreasing invasive surgical mediastinoscopies by 58% avoiding 1,300 operations per annum (**Rintoul Impact Case Study**). Gilbertson co-authored the NHS Long Term Plan for Cancer and the new WHO Brain Tumour Classification and Chairs the NHS Cancer Innovation Committee. Borysiewicz and Ponder serve on the CRUK Board of Trustees.

- ***Cardiovascular and Respiratory:*** research underpins the 2015 NHS Clinical Commissioning Policy and NICE guidance on the use of Rituximab for the treatment of ANCA-associated vasculitis (**Jayne et al Impact Case Study**). This helps set national healthcare research priorities through the NIHR-British Heart Foundation Research Collaboration. The Heart and Lung Research Institute (Section 3.3.2) will serve also as an international convening point to ensure sustainability of our research over the next assessment period. Summers co-authored the UK Guidelines for management of critically ill patients with COVID-19.

- ***Infection and Immunity:*** Peacock is Director of the National Infection Service since 2019 and Executive Director and Chair of the COVID-19 Genomics UK Consortium (COG-UK), and Public Health England Director of Science (Pathogen Genomics); providing critical information to SAGE regarding the UK COVID response. They provide direct advice to the US Centres for Disease Control and WHO on pandemics, and in particular for the 2014 Ebola crisis and the current COVID-19 pandemic (**Goodfellow et al., and Peacock et al., Impact Case Studies**).

- ***Metabolism and Endocrinology:*** Cox led establishment of eight NHS-specialised centres for the treatment of lysosomal diseases and his research supported multiple 2018 FDA and European Medicines Agency recommendations for Gaucher disease treatments (**Cox et al., Impact Case Study**). Karet led development of the UK National Renal Research Strategy. Since 2013, Evans has served on the National Executive Steering Group of the Dose Adjustment For Normal Eating (DAFNE) network, a NICE-approved education programme that has trained >50,000 adults with diabetes.

- ***Women and Children's Heath:*** Aiken and Smith authored a chapter in the Chief Medical Officer's 2014 Annual Report; Smith was a named advisor in a National Screening Committee review of screening for stillbirth; participated in all five elements of the NHS England Saving Babies' Lives Care Bundle version 2; and has authored multiple Royal College of Obstetrics and Gynaecology Clinical Guidelines (**Smith et al., Impact Case Studies**). Rowitch was appointed 'Genomic Champion' by Royal College of Paediatrics and Child Health (RCPCH) in 2019, as RCPCH representative to the UK Joint Committee on Genomics in Medicine (2020) and to the National Advisory Child Health and Human Development Council (NACHHD), National Institutes of Health (USA) in 2020.

4.4.2. Membership of key advisory and funding panels

Many of our members sit on the Scientific Advisory Boards of leading academic institutions around the world. In addition, seven UOA1 staff members (Ashcroft, Clatworthy, Farooqi, Franklin, Goodfellow; Göttgens, Lehner) sit on six different MRC grant review bodies, and two sit on the CRUK Clinical Review Committee (Coles, Gilbertson). O'Rahilly chairs the UK Nutrition Research Partnership for Health and Disease. In keeping with their leadership in organ transplantation (one of our Impact Case Studies), Watson Chairs the NHS Blood and Transplant Kidney Advisory Group 2013-2019 and sits on the NHS Blood and Transplant Clinical Trials Unit Data Safety Monitoring Committee 2018, while Nicholson serves on the NIHR Efficacy and Mechanism Evaluation (EME) Board and Royal College of Surgeons of England Research Board.

4.4.3. Journal editorship

UOA1 staff are members of the editorial boards of >60 leading biomedical journals, including:

- ***Cancer*** *Cell Stem Cell, Cancer Cell* -Gilbertson; *Gastroenterology, Gut*- Fitzgerald; *Blood* -Göttgens and Vassiliou; *European Radiology* -Sala; *PLoS Medicine* -Brenton).

- ***Cardiovascular and Respiratory*** *Atherosclerosis Thrombosis and Vascular Biology* -Mallat; *Thorax* -Floto; *Pulmonary Circulation* - Morrell (Editor-in-Chief).

- ***Infection and Immunity*** *J of Pathology*-Coleman; *Malaria Journal, Trends in Parasitology*-Rayner)

- ***Metabolism and Endocrinology*** *Journal of Clinical Endocrinology and Metabolism, Cell, Cell Metabolism* -Farooqi; *British J of Diabetes, Diabetic Medicine* -Evans [associate editor]; *Diabetes Technology and Therapeutics*, *Journal of Diabetes Technology and Therapeutics* -Hovorka; *Diabetologia, Journal of Endocrinology, Quarterly Journal of Medicine, Diabetic Medicine, Journal of Clinical Endocrinology & Metabolism, Reviews in Endocrine & Metabolic Disorders, PLOS Biology, Cell Metabolism, Disease Models & Mechanisms, EMBO Molecular Medicine e*-O'Rahilly; *Thyroid* -Chatterjee; *Expert Reviews in Molecular Medicine*- Cox (Editor-in-Chief); *Am J Physiology* -Savage; *PLoS Biology, Diabetes, PLoS Biology, Biochim Biophys Act, Trends Endocrinology and Metabolism* -Vidal-Puig; *International Journal of Obesity, American Journal of Physiology, Frontiers in Epigenomics, Endocrinology* -Ozanne; *Endocrinology, Diabetes & Metabolism* -Gurnell (Editor-in-Chief).

- ***Women and Children's*** *Glia, Neuron* -Rowitch; *PLoS-Medicine* -Smith; Clinical *Epigenetics, Scientific Reports and Frontiers Cell, Journal of Immunology and Developmental Biology*-Constancia; *Physiological Reviews, Reproduction, Placenta* -Charnock-Jones; *Reproductive Biomedicine Online*- Aiken.

4.4.4. Engaging diverse communities and the public

The Schools of Clinical Medicine and Biological Sciences share a joint **Patient and Public Engagement Strategy** enabling coordinated partnership with these key stakeholders. Each SRC and CCT hosts discipline-specific patient and public involvement and engagement programmes strengthened by patient networks in our NHS partners. Key elements of this Strategy include:

- **We inspire the public and listen to their views:** UOA1 researchers engage directly with the public about their research through constituent-level and UOA1-wide activities. These events include debate and workshop formats to interact with and gather patient and public feedback:

- ***The Naked Scientist:*** Created and launched in 2001 by Dr Chris Smith (***Infection and Immunity***), it is now one of the world's most popular science shows, with >50 million programme downloads in the last 5 years. Working with the BBC, ABC (Australia), Primedia (South Africa), Talk Radio Europe and Radio New Zealand, the Naked Scientist is syndicated globally to audiences exceeding 1 million people/week. The Naked Scientist internship programme develops and nurtures early-career communicators. The Naked Scientist has won 9 national and international science communication awards, including the Royal Society's 2008 Kohn Medal.
- ***Annual Cambridge Science Festival:*** In 2019 this annual event hosted >170 talks, interactive demonstrations, film showings and debates with the assistance of >1,000 University staff and students, charities and industry, attracting >700 members of the public and >1,500 researchers.
- ***Engagement with local schools,*** particularly those in areas with low science capital or without direct access to scientific research and researchers, through University work experience for Year 10 students, whole-day on-site visits, and road-shows to local sixth form colleges as part of the national 'Big Biology Day' initiative.
- ***SRC-specific engagement strategies*** include: Cambridge Immunology Network (***Infection and Immunity***) annual Science week and public seminars, https://www.immunology.cam.ac.uk/). ***Metabolism and Endocrinology*** 'Lifelab', part of the 2019 European Researchers Night which included 24-hour pop-up festivals across Cambridgeshire, Essex and Suffolk targeting areas with low levels of participation in higher education. And, the Girlguiding Cambridgeshire East STE million Day, aiming to inspire girls to participate in STEM activities. The Cambridge Experimental Cancer Medicine Patient Public Involvement group (***Cancer***) provides input from cancer patients and carers into early phase and translational research. In 2020, this group doubled its membership to 16, held four group meetings, and reviewed six research projects. This group also co-organises our annual patient- and public-facing engagement day. In 2019, this free, all-day event was attended by 120 members of the public, up from 60 in 2018 and rated as 'excellent' by 59% of attendees.

- ***We engage patients in research*****:** The Patient Led Research Hub (PLRH) established in 2015 is a partnership between our ***Clinical Trials CCT*** (Section 1.2) and Cambridge University Hospitals, founded on the principle that ***patients understand their disease and needs better than many medical professionals do and therefore have important ideas about what research would be most beneficial to their lives*****.** In addition to engaging patients in clinical trial planning and review, the PLRH supports patient-led research to deliver clinical studies addressing their own research questions, for example: ***K+ Monitor,*** developing hand-held potassium monitors for home use by patients with dyskalemias; and ***My Sjögren's Diary*** a collaboration between Sjögren's Cambridgeshire and the ***Clinical Trials CCT*** to develop a diary app to assist patients with Sjögren's Syndrome manage their healthcare needs.

- ***We engage diverse communities directly:*** UOA1 is committed to maximising the impact of our research on human health, regardless of patient race, ethnicity or geography. The UOA1-led **AIMHY** trial is seeking to redress ethnic imbalances in treatment of hypertension among patients of African/Caribbean and South Asian ethnic origin –the UK's largest ethnic minority groups. Internationally, we engage with hard-to-reach populations to address key clinical problems. **Cambridge Africa** (Section 1.5.2) and the University of Makerere collaborated on *Africa's Voices* to address disparities in maternal health between African and high-income countries. This project embedded patient and public engagement teams in its research design, using methods grounded in African social realities and deployed widely used communication channels and local languages, for example broadcasting weekly interactive shows through Kampala-based radio stations and sending free text messages, yielding 4,462 SMS from >2,000

people. These data directly informed healthcare workers women's decisions to seek maternal health services.

4.5. WIDER INFLUENCE AND RECOGNITION

4.5.1. Elections to learned societies

Twelve percent (48/389) of UOA1 staff are Fellows of the Academy of Medical Sciences with 18 members elected since REF2014. Sixteen are Fellows of the Royal Society with nine elections since REF 2014, including Ramakrishnan who was also elected to the US National Academy of Sciences in 2015 (Box 1.2). Fifteen UOA1 staff are members of the European Molecular Biology Organization (EMBO), 11 elected since REF2014. UOA1 also includes 7 Wellcome Trust Principal Research Fellows and 9 Wellcome Trust Senior Research Fellows, 13 NIHR Senior Investigators and 2 NIHR professors.

4.5.2. Distinguished prizes and lectureships

As testimony to the quality of its research and leadership, since REF2014 UOA1 staff have received prestigious awards, including:

Cancer: American Association for Cancer Research Susan Komen Outstanding Investigator Award for Breast Cancer Research (Carroll); Gold medal European Society of Radiology (Gilbert); CRUK Future Leader Prize (Markowetz); International Society on Thrombosis and Haemostasis Investigator Recognition Award (Ouwehand); Wolfson Research Merit Award (Markowetz); UK Chronic Lymphocytic Leukaemia Forum Hamblin Prize (Ringhausen); Mary Lyon Medal (Odom); The British Association for Cancer Research Translational Research Award (Rosenfeld); World Molecular Imaging Society Gold Medal (Brindle); Honorary Fellowship Radiological Society of North America (Gilbert); Institute of Physics Paterson Medal, WISE Research Award and JN million AlaviMandell Award (Bohndiek); United European Gastroenterology Research Prize (Fitzgerald); New York Stem Cell Foundation Robertson Stem Cell Investigator Award (Merkle); Arthur de Schepper Lecturer (Gilbert); The Altman Lecture (Gilbertson); Royal College of Physicians Croonian Lecturer (Fitzgerald); Royal Society Francis Crick Lecturer (Odom).

Cardiovascular and Respiratory: Royal College of Surgeons of England, Hunterian Professorship and Medal (Sadat); John Vane Society Medal, European Respiratory Society Lifetime Achievement Award (Morrell).

Immunity and Infection: Basser Global Prize (Venkitaraman); Lister Prize (Nathan); Lupus Research Institute Distinguished Investigator Award (Smith); Albert B Sabin Gold Medal (Dougan); Time 100 most influential (Gupta); Royal Society Buchanan Medal (Griffiths); British Society for Parasitology CA Wright Memorial Medal (Rayner).

Metabolism and Endocrinology: Biochemical Society Keilin Memorial Lecture and Medal (Murphy, 2016; Hirst, 2020); Royal Society Buchanan Medal (Griffiths); Royal Society of Chemistry Interdisciplinary Prize (Hirst); Taubman Prize, University of Michigan (O'Rahilly); Banting Medal for Scientific Achievement, American Diabetes Association (O'Rahilly); Outstanding Scientific Achievement Award, American Diabetes Association (Farooqi); EASD/Novo Nordisk Foundation Diabetes Prize for Excellence (O'Rahilly); Grodsky Award, Juvenile Diabetes Research Foundation (Hovorka); Florence May McCredie Lectureship, Melbourne (Karet); Harveian Oration 2016 Royal College of Physicians, London (O'Rahilly); JBS Haldane Lecture, Genetics Society (Yeo).

Women and Children's: British Society for Paediatric Endocrinology and Diabetes James Tanner Award (Dunger); International Society for Pediatric and Adolescent Diabetes Prize of Achievement

(Dunger); Royal College of Obstetricians & Gynaecologists Annual Academic Award (Smith); Paul G Allen Distinguished Investigator (Rowitch).

4.6. OUR RESPONSE TO THE CORONAVIRUS PANDEMIC

The UOA1 response to the 2020 coronavirus pandemic crisis was enabled by our Research and Impact Strategy and aligned research environment that has allowed us to pivot research rapidly to address specific challenges posed by the pandemic.

4.6.1. Advancing understanding of coronavirus disease

Peacock (***Infection and Immunity***) is the Executive Director and Chair of the COVID-19 Genomics UK Consortium (COG-UK). As of December 2020, COG-UK has generated over 160,000 SARS-CoV-2 genomes, roughly 50% of all COVID-19 genomes generated globally to date, which are used in public health decisions and made available globally in open access databases. These data led directly to the discovery of a new highly virulent variant (lineage B1.1.7, termed VOI 202012/01), associated with a major upsurge in cases, resulting in a significant change in government policy in late December 2020. Consequently, COG-UK received a further GBP12 million from the Testing Innovation Fund to increase sequencing capacity and the Secretary of State for Health and Social Care announced in December 2020 >GBP200 million for a new public health-led national genomics network.

4.6.2. Enabling early and accurate diagnosis of coronavirus infection

In April 2020, AstraZeneca, GlaxoSmithKline and the University formed a joint COVID-19 diagnostics facility in the Anne McLaren Building and CRUK Cambridge Institute. This became one of a network of 'Lighthouse Labs' across the UK for high throughput COVID-19 testing.

We developed and ran the first point of care coronavirus staff test in the NHS and publishing the first account of asymptomatic staff screening in the UK which was presented to SAGE (Weekes et al *eLife* 2020). This work was complemented by the UOA1-led COVIDx study that evaluated the SAMBA II SARS-CoV-2 diagnostic machine that was invented by UOA1 (Lee, CEO of Diagnostics for the Real World). The SAMBA II test takes 90 minutes allowing rapid diagnosis of patients with suspected COVID-19 in the Emergency Department, so that patients can be transferred to the appropriate area of the hospital (red or green) to reduce the risk of hospital-acquired infections. SAMBA II has since been deployed in numerous hospitals. UOA1 also led the UK's first University-wide student screening programme, providing weekly surveillance for coronavirus infection (asymptomatic and symptomatic) during the first term of the 2020-21 academic year. Our 'Lighthouse laboratory' conducted all testing and, uniquely, positive samples underwent genome sequencing. These were the first genomic data on transmission and outbreaks in Universities, and are being used by modellers, SAGE and ministers.

4.6.3. Developing effective new therapies and intervention strategies for coronavirus disease

UOA1 led significant work packages in the national RECOVERY Trial (Randomised Evolution of COVID-19 Therapy) to identify coronavirus disease treatments. In collaboration with King's College London and with NIHR support, UOA1 staff are leading the testing of re-purposed (TACTIC-R) and experimental (TACTIC-E) drugs as preventatives of severe organ failure or death in patients with coronavirus disease. UOA1 also created a nationally accessible NIHR COVID-19 Bioresource with over 6,000 volunteers recruited, and EpiCov database from approximately 111,000 patient records enabling rapid recruitment and study of patients and controls, including recruitment to national clinical trials e.g., the Oxford AstraZeneca vaccine studies.

To alleviate pressure on the NHS, UOA1 conducted modelling on hospital bed availability (made available online rapidly via MedRxivat). And, to mitigate the drastic curtailing of endoscopy services, launched a Cytosponge clinic for two week wait patients and a Cytosponge surveillance clinic for Barrett's oesophagus as part of Innovate UK (publication Lancet Gastro & Hepatology August 1 2020).

4.6.4. Supporting our staff during the coronavirus pandemic

Mindful of the career-impacting effects of the pandemic and particularly its effects on those with caring responsibilities (which are proving particularly relevant to women), the School revised its appraisal paperwork to take specific account of these issues, and the University will be including their consideration in future promotion rounds.

ENVIRONMENT SUMMARY

We have made striking progress since REF2014: generating scientific advances, societal impact and improvements in health in the UK and globally. Our research is supported by an extraordinary ecosystem with state-of-the-art infrastructure, and powerful strategic partnerships with NHS organisations, research institutes and industry, all within walking distance. We strive at all levels, across the whole organisation, to ensure a positive, nurturing and collaborative research environment in which everyone can reach their full potential, and generate data and discoveries that are openly accessible, robustly reproducible and are translated for the benefit of patients and society. We have a comprehensive strategy, a vibrant environment and remarkable talent pool in place to further progress our mission over the next decade, which is to reduce human morbidity and mortality through research that uncovers the basis of health and disease, discovers novel diagnostic and treatment strategies, and deploys these insights to transform medical practice.