Institution: University College London (UCL)
Unit of Assessment: 4 (Psychology, Psychiatry and Neuroscience)
1. Unit context and structure, research and impact strategy

1.1 Overview: Context and structure

UCL's research in psychology, psychiatry, and neuroscience aims to advance our understanding of mind, brain and behaviour to improve global health and wellbeing. The 402 staff (380 FTE) returned in this Unit of Assessment (UoA) engage in basic, clinical, and translational research, lead clinical trial networks, collaborate extensively with other researchers nationally and internationally, and train the next generation of researchers in these fields. This research is catalysed by strong links with multiple NHS Trusts, underpinned by two National Institute for Health Research (NIHR) Biomedical Research Centres (BRCs) and an Academic Health Sciences Centre (UCL Partners, UCLP). The vitality of this research is demonstrated by:

- Outstanding facilities and infrastructure, and major investment in staff, buildings, and equipment in the REF period. In 2016 we were chosen to host the £280M multi-centre UK Dementia Research Institute (UKDRI) which will transform treatment and care for people with dementia;
- Over 28,000 peer-reviewed research articles published during the assessment period. The impact of this work is demonstrated by >470,000 citations, and over 670 'highly-cited' articles (top 1% for their field). On both impact measures we rank internationally second only to Harvard for psychology, psychiatry and neuroscience, and 3 of the top 5 most cited researchers in the UK for this area in the REF period are included in this submission (**Fox**, **Hardy**, **Zetterberg**; InCites);
- Comprehensive external collaboration including contributions to major international and national research networks: 54% of our research outputs include an international co-author;
- An environment designed to foster and actively promote interdisciplinarity: 60% of staff in this submission are involved in interdisciplinary collaborations, and 30% of our submitted outputs include an author from a different UCL UoA (the rule we have adopted to identify outputs as interdisciplinary in REF2);
- A broad and inclusive range of activities and initiatives designed to realise our researchers' potential, including the development of early scientific careers, and embedding equality, diversity and inclusion in all aspects of our research, for example through structured mentorship programmes;
- Research activity sustained by vibrant doctoral training programs which award over 200 PhDs annually, with a 15% increase over the REF period;
- External research awards of over £720M, with average annual income 120% higher than the previous REF period, and equating to over £270K of yearly external income per staff member;
- Substantial engagement with industry, with £32M of funding in the REF period, leading to major and diverse impacts as described in our impact case studies and including >800 publications with an industry co-author;
- Major contributions to the national effort to combat the COVID-19 pandemic, ranging from public engagement via evidence briefings, to ground-breaking diagnostics on COVID-19-related neurological disease, and online therapy delivery for stroke patients.

This submission comprises research activity within UCL's Faculty of Brain Sciences (FBS; Dean, **Thompson**)[1], one of four Faculties constituting the UCL School of Life and Medical Sciences (SLMS). Research is conducted in 7 major units to which all UoA4 staff are affiliated: **Division of Psychiatry** (DoP; Director, **Lewis**); **Division of Psychology and Language Sciences** (P&LS; **Fonagy**); **Ear Institute** (EI, **Gale**); **Institute of Cognitive Neuroscience** (ICN;

[1] The submission is coextensive with the Faculty, comprising all FBS staff who meet the criteria set out in UCL's REF Code of Practice. The only exception is that 5 staff within the UCL Interaction Centre are submitted to UoA11 (Computer Science and Informatics).

Scott); **Institute of Ophthalmology** (IoO; **Dick**); **Institute of Prion Diseases** (IoPD; **Collinge**); and **Queen Square Institute of Neurology** (IoN; **Hanna**).

Research in UoA4 is strategically closely aligned with the our partner NHS Trusts, exploiting co-location of UCL academics with the following Trusts: University College London Hospitals Foundation Trust (UCLH), including the National Hospital for Neurology and Neurosurgery (NHNN); the Royal National Throat, Nose and Ear Hospital (RNTNEH); Moorfields Eye Hospital Foundation Trust (MEH); the Royal Free London Foundation Trust; Camden and Islington Foundation Trust (C&I); and the North East London Foundation Trust (NELFT).

1.2 Mission and strategic principles

FBS has formulated an ambitious strategy that incorporates its core values and develops the complementary expertise contained within its constituent parts to realise our shared mission and vision, in alignment with the major aims of the UCL Research Strategy (see REF5a).

The mission encompasses the full translational pathway spanning discovery science through experimental medicine, to disease prevention and the delivery of new treatments and therapies, across the major research themes shown in Figure 1. It goes beyond disease to inform also our understanding of the neural processes underlying behaviour and how they can be modulated. Moreover understanding and influencing human behaviour are key to the effective translation of science into policy and practice. Behaviour is fundamental to delivering evidence-based interventions by clinicians/practitioners, public health specialists and planners and in maximizing the uptake of such practices by patients, the general population and policy-makers.

Our research thus encompasses genes, molecules and cells, systems, behaviour, and complex interventions in a manner that allows maximal alignment and collaboration with major emerging initiatives and partners. Key strategic mechanisms to realise these research and impact goals are:

- **Investment in major research centres and institutes:** maintaining a vibrant research environment and infrastructure, based around strong research groups led by outstanding individuals and funded by regular and longer-term research grants;
- **Crossing boundaries between disciplines and communities:** fostering interdisciplinary and inter-institutional collaboration and partnership with community, governmental and industry stakeholders in developing solutions to society's most pressing challenges, via mechanisms described below; supported and facilitated by cross-School Neuroscience and Populations & Lifelong Health Domains and UCL's Grand Challenges programme (especially the Global Health and Human Wellbeing themes);
- **Nurturing research leadership:** maximising the opportunities available to the UoA's researchers, optimising their career development, supporting those from under-represented groups, and amplifying the impact of their research as widely as possible, via a range of mechanisms including mentoring and leadership programmes plus continual interaction within and across research groups;
- **International engagement and collaboration:** interacting globally through international institutional collaborations (e.g., Max Planck Society, Yale), training networks, hosting conferences and a high intensity of international conference participation, visitor exchanges, major involvement in editorial work for leading international journals, plus staff and student recruitment;
- **Enterprise and knowledge exchange:** incentivizing and supporting this key aspect of the research of staff members and the research centres to which they are attached via institutional structures and procedures, recognizing our responsibility to society and realizing the public benefit of our research discoveries;
- **Well-resourced state-of-the-art doctoral programmes:** running training programmes with significant teaching components (including PhD-specific courses in theory, methods, core skills and career development), opportunities for international exchange and extensive interaction with experts.

1.3 Development of the research environment since REF2014

We have made substantial progress towards these aims, supported by significant levels of institutional investment in people and infrastructure, as well as major research expansion.

In 2016 UCL won the national competition to be the Hub of the **UK Dementia Research Institute**, coordinating and operating alongside 6 other Centres based at 5 UK Universities (Cambridge, Cardiff, Edinburgh, Imperial, KCL). Launched in 2017, UKDRI is the single biggest investment the UK has made in dementia thanks to £280M from founding funders the Medical Research Council (MRC), Alzheimer's Society and Alzheimer's Research UK (ARUK). The UKDRI HQ is led by **De Strooper** and the UCL Hub by **Duff** (recruited from Columbia University). UKDRI leads the UK's dementia research efforts to tackle the huge challenge of the condition, which is now the leading cause of death in England and Wales. It brings together world-leading expertise in biomedical, care and translational dementia research comprising 60 Principal Investigators and over 650 researchers, support staff and students. The Institute carries out research relevant to all dementias, including Alzheimer's Disease (AD), Parkinson's Disease (PD), frontotemporal dementia (FTD), motor neuron disease (MND), vascular dementia, and Huntington's Disease (HD).

Key to the success of UKDRI is the development of collaborations with researchers from across UCL's research base including the **Francis Crick Institute** and **Sainsbury Wellcome Centre**, as well as engaging with other UKDRI Centres and international networks. Collaborations extend across other disciplines, including UCL Computer Science, for example with Dr Neil Oxtoby, an expert in applying computational approaches in understanding progression of neurodegenerative disorders.

Another strategic focus has centred on mental health and well-being. Following the successful launch of the UCL Mental Health strategy in 2019, a new **Institute of Mental Health** (IoMH) was established and **David** recruited as Director, made possible through a donation of £1M by the Sackler Trust and £0.4M from UCL for core staff and pump priming. The IoMH will facilitate and focus activity in mental health across UCL, spanning psychiatry, psychology, neuroscience, and epidemiology. As a measure of our breadth and depth, a recent audit revealed over 800 potential IoMH affiliates (academic staff, clinical collaborators) who have published relevant research between 2016-2020. These developments put us in a strong position to compete for major funding initiatives: for instance, **Roiser** (supported by **Osborne** and **Fearon**) was awarded £5.7M by Wellcome Trust (WT) for a new IoMH doctoral training programme in MH Science, for 25 studentships over 5 years.

Implementation of the strategy will enrich UCL's mental health research community and outward presence, particularly novel cross-disciplinary activities capitalising on UCL's unique strengths in mechanistic and population health. Discussion with C&I is progressing regarding the redevelopment of the St Pancras Hospital site to provide space and facilities for the IoMH and enhance translational research through co-location of UCL clinical academics within the NHS Trust.

UCL Partners, UCL's Academic Health Sciences Centre/Network, is one of the world's largest academic health science partnerships, covering a population of 6M people in North London and surrounding areas, aimed at accelerating the translation of scientific discoveries into clinical practice by coordinating discovery science and facilitating clinical trials. Its Mental Health and Behaviour Change Programme (directed by **Fonagy**) has a budget of ~£1M pa.

Health services and applied research has been strengthened by the **Collaborations for Leadership in Applied Health Research and Care (CLAHRC) North Thames** (NIHR £10M) and its successor, the **Applied Research Collaborations (ARC) North Thames** (NIHR £9M), supplemented by >£30M from other contributing institutions, involving several staff including **Fonagy** (Mental Health Theme Lead), **Osborn** (Multimorbidity Lead)**, Livingston** (Dementia), **Pilling** and **Johnson** (Adult Mental Health), **Michie** (Behaviour Change), and **King** (PRIMENT Clinical Trials Unit [CTU]). These collaborative networks link UoA4 to UCLP and more than 40 organisations including NHS, higher education, local authority and patient groups to identify and evaluate interventions to improve health and social care.

Two partnerships between NIHR and UCL, renewed in 2016, have provided extensive investment in collaborative experimental medicine research and strongly leverage support from other funders. The **UCLH Biomedical Research Centre** was awarded funding of £114M and expanded to include themes in deafness and hearing, dementia and mental health, and neurological diseases, all led by UoA4 researchers. UCLH BRC invests in staff, equipment, facilities and training, taking innovations in basic science and translating them into treatments and therapies. In particular it supports first-in-human studies including early-phase translational studies,

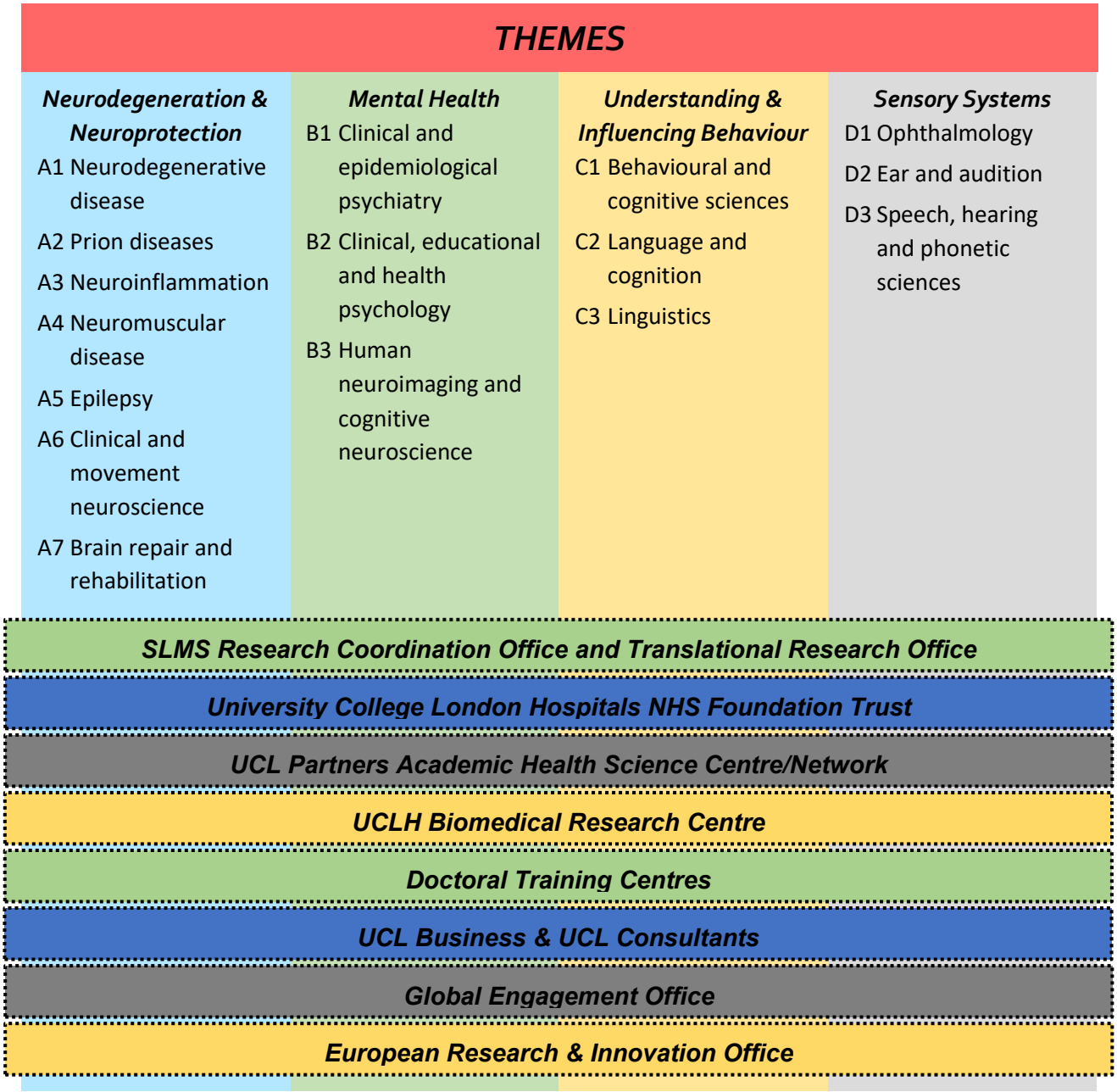

Figure 1. Columns: research themes and sub-themes. Rows: key partners for facilitating research translation.

improvements in diagnosis, treatment selection, evaluation of response to therapies, and repurposing (discovering new uses for existing therapies).

The partnership and combined impact of our joint research with MEH has been sustained though their joint designation as the **Moorfields Biomedical Research Centre** with funding of £19M (Director, **Khaw**). This facilitates the infrastructure and support required to build on fundamental discovery research in vision science and enables rapid delivery of new diagnostic methods and therapies into the clinical setting, closely aligned with the Eyes and Vision theme within UCLP to maximise opportunity in key common areas in personalised medicine, lifelong health, global reach, partnership working, industry engagement, patient and public involvement, and research capacity development. There is strong engagement with industry (recent major contracts with GSK, Roche, Pfizer and Santen), successful spin-outs and spin-in initiatives and extensive collaborations with centres in the US and Europe.

In 2017 the MRC Prion Unit became incorporated into UCL as the **Institute of Prion Diseases** and relocated in 2018 to the newly refurbished Courtauld Building (a joint £30M investment by MRC and UCL) providing a national centre of excellence to pursue a long-term

research strategy in prion and related neurodegenerative diseases involving protein misfolding. This facility includes highly specialised microbiological containment level III laboratories and tissue culture suites and a variety of comprehensive advanced analytical and microscopy facilities with appropriate biosecurity. The incorporation into the university has allowed expansion of its research into understanding the role of protein polymerisation in other human diseases. The Institute has a national strategic role in analysis of prion pathogens.

The **Max Planck-UCL Centre for Computational Psychiatry and Ageing** (Director, **Dolan**), a £6M joint investment between UCL and the Max Planck Society, opened in 2014 in newly-refurbished space. The Centre award was renewed 2019-24 (£2.5M) and it also has partnered with Telefonica (£1.6M industrial collaboration) to develop app-based tools for early detection and monitoring of depression and anxiety. Its scientific goal is to elucidate causes of psychiatric disorders and life course change.

The UCL **Drug Discovery Institute** (DDI; led by **Whiting**) was launched in 2015 with funding from ARUK of £10M for the first 5 years, recently renewed until 2025 with a further £12M. The spinout company AstronauTx, formed in 2019, has received approximately £9M in seed capital including investment from the Dementia Discovery Fund and UCL Technology fund. Working alongside Institutes at Oxford and Cambridge, its goal is to develop new therapies for neurodegenerative diseases, with a particular focus on modulating astrocytes in the brain. It is housed in the Cruciform Building in laboratories benefitting from a £1M UCL-funded refurbishment.

1.4 Open science and integrity

UCL's high-level commitment to research transparency and integrity are underpinned by the institutional infrastructure and policies described in REF5a, including the **Data Safe Haven** and **Research Data Repository**. All research in this UoA complies with UCL's *Statement on Research Integrity* (which incorporates the principles of the UK *Concordat to Support Research Integrity)*, *Code of Conduct for Research*, and *Statement on Transparency in Research*. These include policies about the use of metrics for Open Research in the context of UCL's commitment (since 2015) to the principles of the *San Francisco Declaration on Research Assessment* (DoRA). Importantly, UCL is a founding member of the UK Reproducibility Network (with **Shanks** as institutional lead). Extensive training and enabling mechanisms (including recognition in promotions criteria) have been developed as described in §2.

Staff across UoA4 have led initiatives to enhance open science principles. 130 staff (34%) have published papers or undertaken activities that specifically aim to promote research reproducibility, including defining guidelines or setting community standards for research procedures or analyses. For example, **Michie** co-authored a now-standard template for better reporting of interventions (TIDieR), and **Shanks** and **Fearon** participated in the collaborative network that developed a consensus-based checklist to improve and document the transparency of social and behavioural research reports. **Carandini** was part of the collaboration that established reproducibility of decision-making in mice, releasing methods and data from 5M mouse choices obtained from 7 laboratories across the world. 197 staff (50%) made research data, software, or code available using open source sharing platforms. Reproducible research is an increasingly important focus for staff, including seeking open science grants (e.g., WT Open Research Enrichment award to fund BonVision: **Saleem**), pre-registering hypotheses and conducting registered reports, and contributing to the design and sharing of open-source experimental and analysis packages (notably **Friston's** Statistical Parametric Mapping [SPM] neuroimaging software, but also including many other examples such as **Love's** neural dimensionality software).

UCL Discovery provides free and unrestricted access to more than 21,000 texts authored by UoA4 researchers. Of all UoA4 articles and conference papers that were accepted from 1 April 2016 (not only those submitted as REF2 outputs), 97% have been deposited in UCL Discovery, are gold open access or qualify for exceptions; 89% comply with or have exceptions to the REF open access policy. Administrative staff time in all units participating in this UoA is specifically allocated to supporting compliance with OA policy.

1.5 Research and impact strategy for the next 5 years

Our research has a particularly broad range of key non-academic users and beneficiaries. This informs our strategic approach that provides specific institutional and UoA mechanisms and incentives targeting measurable impacts for each group. Our key users and beneficiaries are:

- **Patients, their carers and people at risk of conditions affecting health and well-being** who benefit from our development and delivery of new diagnostics, better ways of monitoring disease and novel treatments; and through our work improving the effectiveness of existing treatments and disseminating best practice through training and continuing professional development. Our research has significantly improved the management of adults and children with a wide range of neurological and mental health conditions and also the modification of risk factors in healthy people;
- **Local, national and international healthcare providers** who see lower costs from our interventions reducing risk of disease, and whose referral patterns benefit from our expertise. Approximately half the patients seen at our partner hospitals come from outside Camden, facilitating the development of highly specialized clinical services co-located with academic excellence. This has enabled us to make advances in the investigation and treatment of rare (for example, neuromuscular) disease as well as targeting special user groups such as individuals with hearing impairment. Our expertise allows rapid dissemination and translation of research findings into clinical practice but also establishes standards of prevention, investigation, diagnosis and treatment for these patients nationally and internationally;
- **Industry and entrepreneurs** who partner with us to translate discovery into impact. Our expertise in neuroscience has led to major collaborations in early phase development of new molecules and the repurposing of existing medicines for new indications. We have also been very active in clinical trials (>350 initiated in the REF period) where partnership with industry has led to the development of new medicines for neurological disease; and in work with SMEs in the development, implementation and dissemination of new forms of treatment for neurological and mental health disorders;
- **Professions outside academia** including schoolteachers benefit from our extensive outreach and public engagement work, which includes the co-creation of structures like the Centre for Educational Neuroscience (a collaboration with Birkbeck and the UCL Institute of Education; **MacSweeney**) to effect a two-way dialogue with teaching professionals;
- **Government Departments, non-governmental organisations and other policy makers** via membership of key committees influencing policy through direct interaction; through major input into National Institute for Health and Clinical Excellence (NICE) guidelines particularly with respect to mental health; and through advice provided to UK Government Departments and Ministers of State, all-party Parliamentary Groups, and House of Commons Select Committees;
- **Media and cultural organisations and the public** through raising awareness of our research findings among a broad range of audiences and through dialogue to inform our research priorities.

UCL expects academic staff to seek out and actively pursue opportunities to engage directly with external organisations and key research users in ways that result in the direct transfer of expertise and knowledge to transform and benefit society, as exemplified by our Impact Case Studies. UCL's promotions process, the Academic Career Framework (ACF), explicitly recognizes and rewards these activities. The following subsections describe the major ways in which we promote and deliver research impact across these groups.

1.5.1 Institutional and UoA mechanisms for translating research. UCL provides a range of knowledge transfer and enterprise support mechanisms. At Faculty level these include the Faculty's **Vice-Dean for Enterprise** (**Devlin**) and **Faculty Enterprise Champions** (**Schilder**, **Raihani**, **Whiting**, **McQuillan**, **Marshall**); a Knowledge Transfer and Enterprise Board (chair, **Thompson**) delivers strategic leadership to several UoAs, including UoA4. Research strategy is developed and implemented by a senior executive team including Institute/Division Directors, the Vice-Deans for Research and Enterprise, and others with key roles. Regular meetings of the FBS executive team with all Heads of Research Departments ensure alignment with departmental strategy.

The **Office of the Vice-Provost for Research** oversees all aspects of research support, including a range of services managed by the SLMS **Research Coordination Office** (RCO). This includes a Research Coordinator Team which alerts researchers to new funding schemes, co-

ordinates large and interdisciplinary bids, provides support for early career and fellowship applications including training on grant writing, brings together communities by facilitating events and forums, and develops mutually beneficial relationships with external funding agencies. The **Translational Research Office** (TRO) supports the translation of basic and clinical research into therapies, diagnostics and devices, through interacting with investigators, identifying translatable opportunities, and advising on and accessing suitable funding. The TRO advises on industrial partnership alliance management and provides project management support to steer programmes towards practical endpoints. The SLMS **Neuroscience** and **Populations & Lifelong Health Domains**, and the BRCs, also play lead roles in collaborative funding bids.

The UCL/UCLH **Joint Research Office** (JRO) supports the work of the UCLH BRC, including its Neuroscience Programme, particularly on research governance and standard operating procedures. Its Clinical Research Support Centre sponsors major academic clinical trials and works in collaboration with UCL subject-specific clinical trials units such as PRIMENT.

We also capitalise on UCL-wide support, including: Base KX (the UCL start-up hub); **UCL Business**, UCLB, the university's technology transfer office; **UCL Consultants** (UCLC, consultancy contracting services); **UCL Innovation & Enterprise**; UCL's **Global Engagement Office**, which has supported 67 UoA4 projects with combined funding of £180K; the **UCL Public Engagement Unit** and **Media Relations** team; and **European Research & Innovation Office**, which provides advice about EC programmes and promotes interaction with other EU groups.

Key performance indicators such as invention disclosures, technology transfer and industrial income, new industry-sponsored studentships and consultancy contracts, are used to measure and review the effectiveness and achievements of our approach. Such engagement is managed in the staff appraisal system and recognised in promotions.

1.5.2 Translating research for patient benefit. Our approach to delivering new diagnostics and therapeutics that alter the incidence and course of both common and rare human diseases is to co-localise a critical mass of researchers using key technologies with clinical research facilities and national NHS referral clinics. For example, our clinical neurologists are co-localised with the NHNN, which hosts major national clinics for HD (**Tabrizi**, **Wild**, **Bates**), prion diseases (**Collinge**), MS (**Thompson**, **Ciccarelli**), dementia (**De Stooper**, **Fox**), epilepsy (**Duncan**, **Sander**, **Walker**) and neuromuscular disease (**Greensmith**, **Hanna**). NHNN also hosts major regional neurosurgical facilities, co-staffed by many UoA4 staff. Such co-location has led to the implementation in NHS patients of new path-breaking approaches, such as the use of deep brain stimulation in PD (**Marwan**, **Kennerley**, **Yousry**) and treatments for cluster headache (**Akram**) and obsessive-compulsive disorder (**Zrinzo**, **Joyce**).

The **Institute for Clinical Trials and Methodology** was established in 2014 in conjunction with the transfer of the MRC Clinical Trials Unit into UCL. This has provided an opportunity to bring together cross-Faculty expertise in clinical trials (including PRIMENT), and to strengthen methodological underpinning of the field, creating the largest clinical trials grouping in Europe.

The **Wellcome Centre for Human Neuroimaging** develops non-invasive imaging methods to identify novel biomarkers for diagnosing and treating a range of neurological and psychiatric disorders, including predicting patient outcomes after stroke (**Price**, **Ward**); anatomical phenotyping in PD (**Callaghan**, **Lambert**); abnormal receptor signalling in NMDA antibody encephalitis (**Friston**); neuro-rehabilitative feedback in stroke and dementia (**Crinion**, **Leff**); and predicting mood changes in patients with depression (**Dolan**).

Whilst understanding and treatment of common neurological and mental health disorders allows us to reach many millions of patients, our approach equally emphasises impacts on rarer diseases and special populations with health needs. By exploiting the national reach of our NHS partners, who attract large numbers of specialist referrals, UoA4 staff have developed new diagnostic and therapeutic approaches to conditions such as muscle channelopathies (**Hanna**), progressive supranuclear palsy (**Morris**) and COVID-19-related neurological and neuropsychiatric illness (**Paterson**).

We have made all tests of cognition and language for deaf signers developed over the last 14 years freely available to practitioners on the **Deafness, Cognition, and Language Research Centre** (DCAL) Assessment Portal (**MacSweeney**). We developed and disseminated new interventions for children and adults with language impairments (**Beeke**, **Best**, **Bruce**). For example, the *Better Conversations with Aphasia* initiative is a freely available web-based resource

for clinicians, patients and families to support communication across a range of neurogenic impairments and has >6000 registered users drawn from 51 countries, including 24 developing countries.

By closely aligning and co-locating end-users, psychologists, allied health professionals and clinicians with UoA4 staff, we provide new clinical services for people who do not usually have access to such services. We enhance this strategic approach by leveraging and aligning investment from the BRCs which specifically seek to invest in experimental medicine initiatives (diagnostics and first-in-human therapeutics) leading to patient benefit in a short time frame.

The UCL **Therapeutic Acceleration Support** (TAS) Fund is supported by the MRC *Confidence in Concept* scheme, the WT **Institutional Strategic Support Fund** and the UCLH BRC. It aims to accelerate the transition from discovery science to the early stages of therapeutic development by providing responsive and flexible funding to support preliminary translational work. During this REF period the TAS has supported 18 UoA4 projects (typically Technology Readiness Levels 2-4) with £1.4M of funding.

We have further maximised the opportunities to deliver impact by working with the TRO, which supports UoA4 staff in developing, securing and project managing milestone-driven translational funding (e.g., MRC Developmental Pathway Funding Scheme [DPFS], WT innovator awards, NIHR i4i, EU, Innovate UK etc.). UCL now has the UK's largest MRC DPFS portfolio (22% of all awards) and the overall translational funding under management at the TRO during this REF period was in excess of £67M, £36.5M of which is directly associated with UoA4 staff as principal applicant. We make full use of institutional assets to deliver translational pipelines. For example, we have worked with UCLB in applying novel technologies to pioneer biologics in oncology (**J. Greenwood**, spin-out PanAngium) and develop innovative imaging tools for the early diagnosis and identification of blinding conditions such as glaucoma diabetic eye disease, retinal detachment and macular degeneration (**Cordeira**, spin-out Novai).

We also prioritise working with the voluntary sector to reach populations largely inaccessible to statutory service providers. For example, DCAL has partnered with the National Deaf Children's Society to deliver language development training. DCAL is also a full member of UKCoD, the umbrella body which represents third sector organisations of and for deaf children and adults, enabling them to link their research work more closely with the needs of these populations.

1.5.3 Industry collaboration and economic engagement. Another key pathway to impact is our delivery of collaborative research (aligned, wherever possible, with our research strategy) resulting from successful efforts to foster and sustain productive working relationships with a broad range of commercial organisations. We use institutional resources such as UCLB to provide technical, legal and business planning advice on our development of spin-out companies and industry partnerships, and UCLC to help staff establish and maintain formal consultancy arrangements. In 2018/19 staff established 243 research contracts worth £14.8M.

Enterprise in this submission has been catalyzed by two UCLB-led funds, the **Apollo** and **UCL Technology Funds** (~£100M) which pump prime and de-risk new start-ups. Strategies for successfully competing for research funding operate at several levels. This engagement is not restricted to neurological disease. For example, the UCL Technology Fund's investment in the UoA4 spin-out MeiraGTx (**Ali**, **Bainbridge**, **Michaelides** Impact Case Study), which develops gene therapies for inherited retinal diseases, led to £100M of investment through an IPO. Similarly, the EI works with Autifony, a spin-out biotech from GSK in which UCL is a founder shareholder, to deliver novel assets targeting voltage-gated ion channels in the treatment of hearing disorders. In addition, they collaborate with DeepMind to design a next-generation hearing aid that can recreate normal patterns of speech-evoked neural activity in the brains of hearing impaired listeners using a combination of large-scale electrophysiology and deep learning (**Lesica**). With Genomics England we are developing a new pharmacogenetics testing service for cancer, cardiovascular disease and mental health (**Bramon**). **Rees** and **Keane** collaborate with DeepMind and Google Health. **Keane's** collaboration with DeepMind employs machine learning on thousands of eye scans to identify signs of eye disease and recommend how patients should be referred for care.

Outside biotech, we have extensive collaboration with industry that leverages our experience in behavioural science, cognitive neuroscience, big data, perception, and decision making. For instance, the **Centre for Behaviour Change** (CBC) worked with Action Aid Ireland to integrate behaviour change into their Women's Rights Programme to improve the safety and

economic independence of women and girls in Ethiopia, Kenya and Nepal. A collaboration with Just Giving investigated nudges that enhance charitable donations (**Raihani**). With Toyota Motor Europe and Jaguar Land Rover, a cognitive neuroscience approach studies attention and cognitive control in driving, as well as methods to enhance drivers' safety (**Lavie**). A collaboration with the US National Football League investigates the impact of head injuries during a player's career on cognitive abilities (**Sharot**), while a study with Audible investigated cognitive and emotional engagement in narratives (**Richardson**, **Devlin**).

"Big data" projects with Deutsche Telekom, Telefonica, and dunnhumby have used gamification (Sea Hero Quest) to investigate navigation skills in normal aging and people with mild dementia (**Spiers**), smart phone apps to deliver cognitive tests relevant to monitoring of mental health in the general population (**Dolan**), and data from Tesco's loyalty database to investigate how the trade-off between exploration and exploitation influences consumer purchasing behaviour (**Love**). Our expertise in sensory systems has been used to help NTT Corporation Japan build touch-based navigation aids for the elderly (**Haggard**), and in collaboration with MeiraGtx, develop unique brain-based vision tests to measure if a new gene therapy for children with a heritable eye disease can restore function to retinal cone-receptor cells (**Dekker**). Decision making is another area where we have extensive collaborations. For example, we have worked with sporting organisations (English Rugby, British Sailing, the Football Association) to improve decision making to enhance elite performance (**Walsh**, **Harris**); we partner with BlackRock applying causal models to study investment decisions (**Lagnado**); and with Unilever to help recognize and avoid stereotyping (**Ahmetoglu**, **Harris**).

Our approach and the support of UCLB has enabled the disclosure of 85 new inventions, 3 proof-of-concept projects, 37 priority IP protection filings and 49 licensing deals within the census period.

In conjunction with the UCL **Academic Careers Office** (ACO) (led by **Rees**), the TRO provides mechanisms for supporting industry engagement by early career researchers (ECRs). Six Therapeutic Innovation Networks (TINs) have been established to provide opportunities for ECRs to acquire knowledge and skills from researchers and industry experts and seed-funding to develop and advance novel therapeutics and diagnostics. In 2020, for example, 8 UoA4 ECRs were supported at ~£10K each to collect pilot data for their therapeutic projects. Additionally, the WT Translational Partnership Award (£500K p.a.) provided support to 50 UoA4 ECRs via skills development and innovation through our translational education ACCELERATE scheme.

Joint studentships and fellowships further help to engage industry users with our research. We take advantage of institutional resources such as the ACO, and have coordinated an institutional approach to our MRC/BBSRC industrial CASE studentships that has led to a wide range of collaborative PhD studentships with industry (72 in the assessment period), including the pharmaceutical (AstraZeneca, Eisai, GSK, Merck), manufacturing/technology (Philips, Siemens, Toyota), retail (dunnhumby), and financial (BlackRock) sectors. We are building links with other non-academic bodies such as the Ministry of Defence through shared studentships (**Lavie**, **Hamilton**). A total of 81 FBS PhD students participated in UCL's EPSRC-funded SPERO entrepreneurship training programme and 3 graduate start-ups were created in 2019/20 (for example, the Neurovirt virtual reality and haptics device for upper-limb rehabilitation).

To consolidate these links with industry, we encourage staff to seek awards enabling secondment to industry (for example, **Spiers'** 6 mo secondment to Centric Lab).

1.5.4 Major infrastructure investment. Two major projects representing a combined investment of nearly £800M are at the heart of our forward impact strategy.

UCL is investing ~£280M to create a new state-of-the-art facility for the **IoN** and **UKDRI** national headquarters due to be completed in 2024, transforming the former site of the Eastman Dental Hospital and Institute at 256 Gray's Inn Road, London, and bringing together over 500 research scientists and clinicians. The new building will provide a bespoke translational research environment of ~17,000 m^2 enabling co-location of interdisciplinary basic researchers and clinicians. It will foster new models of open innovation and will support effective engagement with industry, patient organisations, patients, the public, policy makers and funders. It will connect to Europe's largest clinical neuroscience centre, NHNN, assessing 150,000 patients annually, thus enabling unrivalled patient research opportunities. Furthermore, it will catalyse the implementation

Figure 2. Left: Planned new building for the Institute of Neurology and UK Dementia Research Institute at the former Eastman Dental Hospital site on Gray's Inn Road. Right: New home for the Institute of Ophthalmology (and Moorfields Eye Hospital) on the St Pancras Hospital site.

of first-in-human trials carried out at the **Leonard Wolfson Experimental Neurology Centre** (LWENC).

In addition to UCL funding of £120M, this major infrastructure project is supported by awards of £41M from the Department of Business, Energy and Industrial Strategy (BEIS) and £29M from Research England's UK Research Infrastructure Partnership Fund (UK RPIF), and was the highest priority on the UCL Capital Programme. It has stimulated significant private sector investment, with an exceptional consortium of UK retailers providing >£20M from the levy on plastic carrier bags and the Garfield Weston Foundation £5M. Partner charities have made a further commitment of >£20M. This project will significantly strengthen the contribution of the research base to economic growth, with projected gross UK economic benefits of £850M and the creation of >1,800 jobs over 30 years[2].

The partnership between the **IoO** and **MEH** represents the largest co-located site for eye research, education and care in the world. Recent successes include the London Project to Cure Blindness (**Coffey**), which published results in 2018 showing patients regaining sight after receiving retinal tissue engineered from stem cells. It is hoped that this treatment, the first description of a complete engineered tissue successfully used in this way, will also help treat age-related macular degeneration (AMD) in the future.

However, research and clinical services currently operate from separate, outdated buildings, distant from other UCL centres. In a major ~£500M joint project, a new clinical, research and teaching site will be created close to the UCL main campus, bringing together clinical care, research and education, and linking IoO/MEH with the Francis Crick Institute and strengthening collaboration with UCL groups, for example IoN, UKDRI, Institute of Healthcare Engineering and the School of Pharmacy. MEH's main City Road hospital site and IoO will be integrated in a new purpose-built environment on the St Pancras Hospital site in Camden, comprising ~40,000 m^2, of which ~10,000 m^2 will be dedicated to UCL research. MEH has committed ~£350M towards the programme, including NHS capital funding of £110M, and the projected cost to UCL is ~£155M, to be covered via a combination of the sale proceeds of the IoO's current site on Bath Street, a £30M grant from UK RPIF linked to a joint fundraising campaign by UCL and Moorfields Eye Charity, and the UCL Capital Programme. The Sir Jules Thorn Trust have committed £5M towards a new Clinical Investigation Centre. Construction is expected to be complete by early 2026.

The project offers a transformational opportunity to ensure the long-term future of the IoO and MEH as world-leaders in eye health, research, education and care. The facility will support a portfolio of research programmes addressing patient need in the commonest eye conditions of glaucoma, diabetic retinopathy and AMD, underpinned by core strengths in genomic medicine, cellular and molecular biology, AI, neuroscience, physiology and psychophysics. IoO will also benefit from provision of enhanced research facilities such as tissue culture labs, a Biological Services Unit, flow cytometry, and cellular and sub-cellular imaging.

[2] https://www.london.gov.uk/press-releases/mayoral/international-dementia-research-institute

1.6 Research themes

A. Neurodegeneration and neuroprotection

This theme encompasses research applying integrative molecular, cellular, neuroimaging, epidemiological and cognitive approaches to neurodegenerative and related disorders affecting the brain in order to define disease, illuminate mechanisms of pathogenesis, and guide design of therapeutic interventions for disorders of the nervous system. Specific **goals identified in REF2014** were to: (i) establish a world-leading facility for experimental medicine, the LWENC; (ii) strengthen and complement existing molecular and cellular expertise in the neurobiology of neurodegenerative disease; (iii) develop novel therapeutic strategies for neurodegenerative diseases through establishing a pipeline for identifying targets, and molecules affecting these targets; (iv) establish new cross-Faculty and inter-institutional collaborations; (v) and use our expertise to evaluate combinations of biological, psychological and social approaches to dementia care that have impact on both neurodegenerative processes and mental health. Achievements against all of these goals are elaborated below.

Strategic achievements in the REF period

A1. Our research in **neurodegenerative disease** has a strong focus on understanding major neurological disorders including AD, HD, PD and Dementia with Lewy Bodies (DLB), MND, FTD, and brain tumours. Multi-disciplinary bench-to-bedside research programmes span genetics, molecular cell biology, transgenic and knock-in mouse models, neuroimaging, biomarkers, neuropathology, systems neuroscience and experimental medicine.

The research strategy focuses on translating mechanistic insights to therapeutic trials while improving diagnostic and disease-modification measures. To do this, we use well-characterised cohort studies that include high-risk individuals, such as gene carriers and biomarker-positive healthy individuals, to identify the earliest changes of disease and assess markers of early progression. We conduct longitudinal analysis of imaging and biofluid biomarkers in these cohorts to develop valid outcome measures, efficient clinical trial designs, and to identify the optimum time for therapeutic intervention. We are leaders in innovative trials in antisense oligonucleotide (ASO) therapies for neurodegenerative diseases (**Tabrizi** Impact Case Study) and in innovative clinical trial design and execution.

Platform technologies include: genomics; disease models from Drosophila (FTD) to genetically modified mice (HD, FTD, oncology); iPS cell studies; RNA- and protein-based expression analysis technologies for understanding transcriptional and translational processes in HD and PD with bioinformatics expertise in all these areas; genomic editing tools such as CRISPR, zinc finger nucleases, and AAV delivery harnessed across numerous disease areas to monitor functional outputs derived from genomic alterations; and high content screening technology, ultrasensitive immunoassays and mass spectrometry, and super-resolution microscopy techniques.

Industry collaborations with a total value of >£2.1M include Ionis, Roche, Wave, Vertex and Takeda (**Fox**, **Isaacs**, **Rohrer**, **Tabrizi**, **Wild**, **Wray**) developing and delivering ASOs through to cutting-edge clinical trials with significant success, particularly in HD. **Tabrizi** is developing novel drugs to inhibit CAG repeat expansion due to somatic instability in HD with both Vertex and Triplet Therapeutics, and zinc finger AAV delivered gene therapy approaches with Takeda. In PD, **Plun-Favreau** established a collaboration with Cerevance investigating mitochondrial and synaptic dysfunction.

A2. Research on **prion diseases** takes advantage of nationally unique specialised facilities for studying human and animal prions and pathogenic protein assemblies in other neurodegenerative diseases, notably AD and other dementias. These include dedicated microbiological laboratories and an animal facility, as well as specialised robotic platforms for cell-based bioassay of prions and a comprehensive array of equipment for study of infectious protein assemblies including fluorescence, confocal, super resolution, atomic force and cryo-electron microscopy, mass spectrometry, asymmetric flow field flow fractionation and analytical ultracentrifugation.

Major external collaborations include with KCL as part of the EMBED-care collaboration investigating end of life care in dementia; contributing to major international collaborative groups

for genome-wide association study of dementias, leading in prion diseases; and with the Papua New Guinea Institute of Medical Research regarding kuru disease.

A3. Research in **neuroinflammation** is focused on understanding the mechanisms underlying central (mainly MS) and peripheral neuroinflammation, with the goal of developing novel therapeutic strategies for protection of neural function and structure. Our overall strategy is to understand the pathophysiology of neuroinflammatory diseases in order to identify new targets and therapeutics that we translate into clinical trials.

An example of this strategy comes from our original discovery of sodium dysregulation in experimental autoimmune encephalomyelitis, the most commonly used model for MS. This was followed by evidence that axons can be protected from degeneration by partial blockade of their sodium channels using pharmacological agents. To test whether sodium channel blockade provides neuroprotection in MS we have carried out two clinical trials, one with phenytoin, which won the 2016 MS Research Prize for 2016 (**Kapoor**, **Smith**). The MRI analysis of these trials has been performed by the MS Trial Office (**Ciccarelli**, **Barkhof**), which has been the imaging analysis centre of 11 clinical trials during the REF period. The most recently initiated trial, funded by the NIHR-HTA and MS Societies (**Ciccarelli**, **Barkhof**, >£5M), is a phase III trial (MS-STAT2) which aims to test the efficacy of simvastatin in secondary-progressive MS from more than 20 centres in the UK. This has followed the phase II trial (MS-STAT) which showed that simvastatin reduced the development of brain atrophy in MS. A recent award (UK MS Society, £13M; **Ciccarelli**, **Barkhof**, **Thompson**) is for a platform trial that will use a novel multi-arm, multi-phase design to identify effective treatments in progressive MS.

Important insights into the mechanisms of MS have been provided by our longitudinal, observational MS cohorts, whose follow-up visits at 5, 14, and 30 years (**Chard**, **Ciccarelli**) have led to the identification of MRI biomarkers which predict disability and are now routinely used clinically. The physics team led by **Wheeler-Kingshott** has developed advanced imaging techniques which have underpinned the design of clinical trials as secondary outcome measures, and include total sodium concentration (BRC, £500K) and spinal cord atrophy.

Platform technologies include: a 3T MRI scanner dedicated for MS research, funded by the BRC and UK MS society; XNAT for managing data and automated processing, with RedCap for clinical variable storage and linkage to MRI; optical coherence tomography in neuroprotection trials; confocal microscopy for real-time observation of physiology in combination with electrophysiology; and induced pluripotent stem cell (iPSC) derived microglia.

Industry collaborations are strong in the MS Trial Office and include Biogen, Novartis, Roche, Eisai, MedDay, and Sanofi-Genzyme; other industry collaborations are with Eisai, Hoffman LaRoche, and Lundbeck. Collaboration with the Centre for Medical Image Computing (CMIC) in UCL Engineering has led to the translation of microstructural, advanced imaging to clinical studies, and extensive collaboration with European and international research groups: for example **Ciccarelli** is a member of the Steering Committee of the European MAGNIMS group, which has developed guidelines on diagnostic criteria and MRI protocols in MS.

A4. Our basic and clinical research in **neuromuscular disease** combines genetic, functional cell biology and neuropathological methods to understand and develop novel therapies for these diseases. Research ranges from spinal cord motor circuits and motor neuron physiology, systems neuroscience, muscle disorders including Inclusion Body Myositis, mitochondrial disease and muscle ion channel disorders, peripheral nerve disease, and a number of neurodegenerative diseases including ataxia. There is particular strength in MND including amyotrophic lateral sclerosis (ALS) and Kennedy's Disease.

Major techniques that underpin this research include human and mouse genetics, RNA biology and protein-RNA complexes, axonal transport and intra-vital imaging, single cell transcriptomics, in vivo physiology and optogenetics, the microbiome, biomarkers, human-induced pluripotent stem cell biology and models, drug discovery, cellular imaging (confocal and multiphoton microscopy), as well as a major commitment to clinical trials. New laboratory spaces, including new wet lab space in Queen Square House (**Brownstone**, **Schiavo**) and a new central animal behaviour suite (**Brownstone**) as well as refurbished laboratories in the Cruciform Building for the DDI (**Whiting**, **Fish**), have enhanced capacity. In vitro and in vivo electrophysiology (**Brownstone**, **Greensmith**) includes the ground-breaking "Neuropixels" electrodes with 1,000

recording sites allowing recordings across the whole brain (**Carandini**, **Harris**) and the first imaging of the activity of populations of over 10,000 neurons in the living brain.

A number of important centres are incorporated including the new MRC International Centre for Genomic Medicine in Neuromuscular Diseases (£3.66M; led by **Hanna**, **Houlden**, **Reilly**) which aims to create a transcontinental genomics research capacity in neuromuscular diseases, building partnership between the UK and Brazil, India, South Africa, Turkey and Zambia. It will establish a core international bioinformatics platform pipeline and clinical and genetic database, to identify known and new disease genes across four continents. Work on novel transgenic and humanised mouse models involves major links to the mutagenesis programme at MRC Harwell (**Fisher**).

A5. The major goal of our experimental research in **epilepsy** is the elucidation of the cellular and molecular mechanisms underlying paroxysmal brain disorders leading to the development of new treatments. Our portfolio covers the complete pipeline from basic science discovery to clinical trials as well as population studies and health service research. Key infrastructure for this work includes a range of cutting-edge experimental techniques, such as time-resolved fluorescence imaging, tri-dimensional, direct stochastic optical reconstruction microscopy, optogenetics and full clinical phenotyping including MRI, fMRI PET, SPECT, Stereo-EEG, EEG-video telemetry, transcranial magnetic stimulation (TMS), visual field perimetry, genomic analysis, facial stereography and therapeutic drug monitoring.

Clinical epilepsy research encompasses genetics, imaging, pharmacology, neurophysiology, psychology, neuropathology, clinical trials focusing on drugs, devices and surgical interventions. It aims at developing precision medicine for people with epilepsy. Recent contributions in genomic research, with a network of international collaborations, include the discovery of genes causing rare syndromes, genetic factors increasing susceptibility to disease, and pharmacogenetic variants and genetic factors related to epilepsy traits.

Translational research includes drug development for personalised treatment for drug-resistant epilepsy, and techniques to improve curative epilepsy surgery supported by over £5M from WT, MRC and Department of Health. A first-in-human trial in collaboration with Vitaflo (**Walker**) has tested a new dietary therapy for epilepsy for which UCL has IP. We also have IP for new gene therapies to treat focal epilepsies (**Kullman**, **Lignani**, **Walker**) with first-in-human trials planned for 2021.

A6. Research in **clinical and movement neuroscience** brings together expertise across the clinical and basic science spectrum of the physiology and pathology of human movement and movement disorders. It incorporates groups from the Queen Square and Royal Free campuses and includes the Reta Lila Weston Institute and the Movement Disorders Centre, the latter established in 2017 with funding from the UCLH BRC and MJ Fox and Safra Foundations. Major research programmes study the aetiology and pathogenesis of PD, Parkinsonisms and tauopathies; the molecular biology of alpha-synuclein metabolism; cell biology of lysosomal and mitochondrial function, dysfunction and turnover; DNA structure and single cell somatic mutation detection; movement neuroscience and motor cortex physiology and behaviour.

These programmes use a broad range of cutting-edge methods, including techniques for studying the molecular cell biology and genetic basis of neurodegenerative diseases and movement disorders; genetic stratification of neurological disorders; deep brain stimulation surgery (hosting the largest centre in the UK); TMS; cortical mechanisms underlying pathological fatigue in neurological conditions, currently focussing on post-stroke fatigue; and identification of prodrome and clinical evolution of PD and genetic subtypes.

Major translational research includes Phase II and III trials funded by NIHR on exenatide and ambroxol for neuroprotection in PD (**Foltynie**, **Schapira**); efficacy of antidepressants in PD (**Schrag**, NIHR, £2M); exploiting MAPT-AS1, a long non-coding RNA, for therapeutic reduction of tau (**DaSilva** with Apollo Therapeutics, £1.5M); transcranial brain stimulation for stroke rehabilitation; therapeutic indications for deep brain stimulation in PD, Tourette syndrome, and obsessive compulsive disease; and novel therapeutics for mitochondrial disease (with Muscular Dystrophy UK). Research funded by Microsoft is evaluating wearable devices to assess and treat motor features in PD. **Schapira** leads the MRC Centre of Excellence in Neurodegeneration, a collaboration with teams in Canada, Italy, and Germany.

A7. Our research in **brain repair and rehabilitation** covers the clinical themes of stroke, neuroradiology, neurorehabilitation, spinal cord repair, autonomic neurology, uro-neurology, neurosurgery, headache, and high-dimensional neurology. We aim to translate neuroscience and mechanistic findings into precision medicine to improve clinical care (diagnosis, treatment, neurorehabilitation).

With an underpinning clinical focus, staff employ a wide variety of approaches, including: experimental models of spinal cord injury (cell culture and transplantation, histological analysis, biomaterial cellular scaffolds); advanced neuroimaging biomarkers to improve patient selection, outcome prediction, and as outcome measures for stroke, neuromuscular diseases, neurodegenerative diseases, brain tumours and prion diseases (**Golay** Impact Case Study); observational studies including imaging, cardiovascular and neurophysiological assessments, neurogenetics, and fluid biomarkers; high-dimensional complex modelling of imaging, physiological and clinical data; randomised controlled trials of drugs, devices and web-based applications; and clinical implementation studies of new interventions.

A major development is the establishment of the **Stroke Research Centre** (SRC), which facilitates multicentre collaborative clinical trials and observational studies, with staff funded by NIHR, BHF and Stroke Association (**Werring**, £2.5M). The SRC unites clinical stroke research with the high-dimensional neurology group, which applies complex modelling to healthcare data, including secure large-scale data storage and computational resource; funding includes a WT Innovations grant to **Nachev** (£4.5M, with KCL). The autonomics group has established a novel controlled autonomic laboratory, while the uro-neurology theme established the first UK pelvic neurophysiology laboratory. The Neuradiological Academic Unit secured a state-of-the art upgrade to their 3T research MRI system (MRC Infrastructure Award; **Yousry**, **Thornton**, £1.2M), and a computational platform for integrating imaging biomarkers into hospital information systems.

Major international collaborations include: advanced vascular and quantitative neuroimaging (**Jäger**, **Thornton**, **Barkhof**, **Golay**, including €6.5M EC funding); neurorehabilitation (Back of the Brain project; **Leff**), spinal repair (**Li**); autonomic neurology; uro-neurology; headache (**Matharu**); MRI in neuromuscular diseases (Myo-MRI COST); and gliomas (**Bisdas**, NIHR funded).

B. Mental health

Research in this theme combines initiatives in clinical and epidemiological psychiatry, clinical, educational and health psychology with discovery neuroscience to address the global challenges of mental health problems. Specific **goals identified in REF2014** were to: (i) create a single knowledge hub for mental disorder with the establishment of **IoMH**, which sits across this area, building on UCL's strengths in neuroscience and treatment research to make major advances in our understanding of the biological basis and development of mental disorders; (ii) apply this knowledge to the design and evaluation of new therapeutic approaches; and (iii) research how evidence-based care is implemented to improve outcomes for patient and population benefit. Achievements towards these goals are now described.

Strategic achievements in the REF period

B1. The aim of our research in **clinical and epidemiological psychiatry** is to address clinical problems in order to achieve benefits for patients and public health, using insights from basic science. We adopt a multidisciplinary approach spanning the full range of specialisms including psychiatry, clinical psychology, epidemiology, systematic review, statistics, genetics, neuroscience, psychology and social science.

The **PRIMENT Clinical Trials Unit** is a cross faculty collaboration that specialises in mental health, primary care and other community based trials. A major programme in clinical trials, mostly funded by NIHR (>£22M) of psychological, pharmacological and more complex interventions has achieved major impact including **Livingston**'s START intervention for carers of people with dementia that is being widely implemented in the NHS (Impact Case Study); **Howard**'s demonstration that donepezil reduces time spent in hospital for patients with AD and the first evidence that antipsychotics are effective in late onset psychosis; **Johnson**'s peer-supported programme that reduces admissions for people with psychosis; and **Lewis**' PANDA trial that found antidepressants were effective for anxiety symptoms in mild depression.

Our applied epidemiological work focuses on longitudinal studies using record linkages and secondary analysis of existing data including UK birth cohorts. We work closely with colleagues in the Karolinska Institute using Swedish data as well as UK-based record linkages in primary care (CPRD) and mental health electronic records (CRIS) in collaboration with KCL. **Hayes** and **Osborn** (Impact Case Study) have developed a cardiovascular risk prediction tool for people with severe mental illness.

In old age psychiatry, **Livingston** led the *Lancet Commission on Dementia Prevention and Care* that has had substantial international impact in promoting interventions to prevent dementia. This has catalysed funding such as **Cooper**'s ESRC grant (£3.8M) to investigate lifestyle changes and **Costafreda**'s project to investigate enhanced support for hearing aids. **Mukadam** has extended this work to low and middle income countries.

Johnson leads the **Mental Health Policy Research Unit** (NIHR £5M), a joint UCL/KCL initiative to provide evidence-based policy guidance to DHSC, NHS England and Public Health England. It provided key evidence for the Wessely Mental Health Act review (**Johnson & Lloyd-Evans** Impact Case Study). **Killaspy** (Impact Case Study) has developed and evaluated methods to improve rehabilitation for those with complex psychosis who have major long term disability.

The Molecular Psychiatry Laboratory aims to characterise genetic variants increasing susceptibility for mental disorders or influencing response to psychotropic medications. We host deep phenotype and genomic data from people suffering from a range of mental disorders including schizophrenia, bipolar disorder and alcohol misuse.

Sampson has developed an intervention to improve care of people with severe dementia approaching the end of life that is being evaluated via an ESRC £3.7M grant. **Stone** (Marie Curie Centre grant £2.3M and NIHR) has evaluated prediction tools in palliative care and, with **Hudson** and **Shulman** (Impact Case Study), has led work in homeless people that has changed NHS policy. A mental health theme within the UCLH BRC renewal, led by **Howard** to encourage translational psychiatry, facilitated project funding for pharmacogenetics prediction of antipsychotic response (**Bramon**) and the development of an intervention to improve sleep in dementia (**Rapaport**).

B2. Research in the areas of **clinical, educational and health psychology** has a strong focus on understanding the causes of and mechanisms that underlie mental disorders, behavioural problems, and educational difficulties. This is complemented by a major objective to develop and evaluate innovative interventions (**Fearon & Fonagy** Impact Case Study).

Key infrastructure for this work includes cohort studies and large secondary individual and group datasets to develop causal models and prognostic and predictive tools for mental disorders and a range health, behavioural and organisational problems; fMRI, EEG and VR to aid in the understanding of the mechanisms underpinning mental disorder and the development of novel interventions; and large-scale multi-centre trial platforms and large (>500K) clinical databases to evaluate interventions and implementation methods.

Major Centres underpin and enhance work in this area. The **Centre for Behaviour Change** (led by **Michie**, Impact Case Study) was established at the end of the REF2014 period and, following significant institutional support (including £370K of seed funding and earmarked space), has grown into a major national and international centre of excellence in public health policy and the theoretical and practical applications of behaviour change. **Michie** plays a lead role in the **NIHR Behavioural Science Policy Research Unit** with strong collaborations with Newcastle, Cambridge, Warwick and the London School of Hygiene and Tropical Medicine, and leads the UCL element of the **NIHR School for Public Health Research**, which has a similar range of university collaborations, with **Osborn** leading the Public Mental Health programme (£3.2M). Another important development was the opening of the new building (the Kantor Centre of Excellence, Rodney Street) for a major partner, the **Anna Freud National Centre for Children and Families** (AFNCCF). This provides facilities for both laboratory-based work (EEG, fMRI), digital mental health interventions and cohort studies. **Fearon**, **Fonagy**, **McCrory** and **Viding** are key collaborators with AFNCC and there are strong links with Cambridge, King's and Yale.

The **Evidence Based Practice Unit** (EBPU), led by **Deighton** (Impact Case Study), focuses on the improvement of mental health and well-being in schools with a range of research programmes including RCT evaluations of school interventions. The **Centre for Outcomes Research and Effectiveness**, led by **Pilling**, is a health services research group focused on

evidence synthesis to support NICE clinical guidelines and health policy initiatives, clinical trials of novel mental health interventions (for example the ODDESSI Programme grant), and the use of large datasets to inform prognostication and prediction in psychological interventions. The unit has been awarded >£5M of funding and recent work has been central to the Green Paper on children's mental health and the NHS Long-term Plan.

B3. The interdisciplinary strategy of our research in **human neuroimaging and cognitive neuroscience** is to study how the brain generates thoughts, feelings and behaviour, and how these processes break down in neurological and psychiatric disorders, combining cognitive psychology, computational neuroscience, anatomical and functional neuroimaging and neuropsychology. Major infrastructure supports MRI/fMRI (3T and 7T), fNIRS, EEG, MEG, TMS, PET, electrophysiology in epilepsy patients, pharmacology, study of cognition in special populations (autism, depression, AD, anxiety, stroke), children and adolescents, computational modelling and SPM, and machine learning. In combination, these support clinically transformative applications of neuroimaging that exploit computational approaches to find biomarkers for early diagnosis of neurological conditions, use biomarkers to re-stratify psychiatric patients into finer groups, provide more accurate prognoses, find ways to identify the best treatments for different patients, and develop better treatments and rehabilitation paradigms.

A magnetically shielded laboratory funded by a WT collaborative award (£870K) with Nottingham University is supporting **Barnes**' ground-breaking development of Optically Pumped Magnetometry, the first mobile MEG system for non-invasively measuring brain function in freely-moving individuals and allowing detection of functional biomarkers at the bedside. Additional space in Alexandra House has been acquired, particularly aiming to facilitate industry collaborations, including **Crinion** and **Leff's** novel online therapeutics development and **Lavie's** driving simulator work with Jaguar Land Rover and Toyota (spin-out MindVisionLabs). fNIRS equipment has been funded by Shimadzu (£500K) to support the work of **P. Burgess** and **Hamilton**, and the latter has also built a motion-capture virtual reality lab (Leverhulme).

C. Understanding and influencing human behaviour

Research in this theme exploits expertise in behavioural and cognitive sciences, neurology and neuroscience to improve understanding of the basic neural and cognitive processes underlying human wellbeing from infant development to aging, and to inform strategies for behaviour change interventions. **Goals identified in REF2014** were to (i) establish state-of-the-art research facilities for the study of cognition and behaviour, including investment in upgrading laboratories (see §3.3); (ii) explore the cognitive and neural bases of behaviour in relation to wellbeing and apply this understanding to improve behaviour change interventions; and (iii) strengthen and complement existing lifespan expertise in behaviour change.

Strategic achievements in the REF period

C1. Our research into the **behavioural and cognitive sciences** has substantially expanded its scope. We have moved from understanding the basis of simple and constrained behaviours in laboratory environments, to understanding complex behaviours of individuals and groups in naturalistic scenarios, including through partnerships with key stakeholders outside academia.

In cognitive and decision science our work provides international leadership in the integration of large scale behavioural and cognitive neuroscience measurements, including in decision making and bias, with a focus on new computational approaches, which we have supported with a nation-leading GPU cluster (£60K) for machine learning to link brain activity to cognition via cognitive models. **Love** is a Fellow at the **Alan Turing Institute**. Research into language and multimodal communication emphasizes naturalistic scenarios. Major projects study word meaning and how large-scale brain networks work together to support language.

These expanded directions have brought new opportunities for engagement with industry partners, including collaboration with Audible on cognitive and emotional engagement from auditory content (**Devlin**, **Richardson**), dunnhumby (**Love**) and Telefonica (**Sharot**) to explore real world decision making, and through new tools to connect researchers to industry (the Behavioural Insights Exchange [BIX] programme; **Devlin**, **Raihani**).

Similarly, our research into sensory science has also broadened towards understanding more complex behaviours. New collaborations investigate how the brain builds and uses

representations of complex, three-dimensional worlds in animals and humans. This area has benefitted from significant investment in new facilities including virtual reality for both human and animal experiments, development of new virtual reality tools (**Saleem**), and mobile brain imaging through fNIRS (**Howell**). It has also produced significant new partnerships with clinicians (**J. A. Greenwood**), and industry, including with Lilly on the development of new measures of neurodegeneration (**Solomon**, **Saleem**), with MeiraGTx on gene therapies in childhood vision (**Dekker**) and with Deutsche Telekom and ARUK to develop and propagate large scale spatial navigation research (**Spiers**).

Research has been strengthened by investment in the expansion of the **Birkbeck-UCL Neuroimaging Centre** (BUCNI) to include a new 3T MRI scanner.

C2. We undertake research in **language and cognition**, spanning developmental and neuroscience perspectives on language processing and disorders. **Norbury** (Impact Case Study) leads the *Surrey Communication and Language in Education Study* (SCALES), the first UK population study of language development and disorder at school entry, with funding from WT and ESRC (>£1M). It focuses on the prevalence of language disorder and improved diagnostic criteria for the condition. **Varley** leads research on aphasic disorder (Stroke Association) and, with funding from AHRC and the Alzheimer's Society, collaborates with the UKDRI, exploiting data from patient cohorts to develop novel automated tools for detecting and tracking language change in dementia. The conversational analysis group (**Beeke**, **Bloch**) collaborates with clinicians in palliative care to explore end-of-life and helpline conversations, and ward-based interactions in dementia.

Translational research developments include digital health innovations (**Clarke**, **Swettenham**). Collaborations with industry partners develop technology to assist in numeracy (**Donlan**, **Bruce**, **Newton**; funded by Nuffield), lexical development (**Best**, ESRC) and language profiling (**Varley**: Frequency in Language Analysis Tool, AHRC). The review period has also seen substantial investment in infrastructure, with refurbishment of aphasia clinic space and facilities for baby research. Capacity for TMS research has been extended with a tDCS system.

The **Deafness, Cognition, and Language Research Centre** (Director, **MacSweeney**) is a multi-disciplinary centre that brings together researchers from linguistics, psychology, and neuroscience, supported by a second ESRC Centre Grant (£5.5M) from 2011-2016. During this time DCAL established itself as a leading centre for research on deafness and language, with a unique record for capacity-building of researchers who are deaf themselves. Its research focuses on how communication and cognition are shaped by deafness and the use of visual language, in particular sign language. **MacSweeney's** WT SRF funded a programme on the neural basis of reading in deaf individuals. DCAL has also established extensive open resources for researchers and practitioners in the field; e.g., *BSL Corpus, BSL Signbank, DCAL Data Research Archive, and DCAL Assessment Portal.*

C3. Research in **linguistics** spans theoretical linguistics and psycholinguistics. The aims of this research are to develop methods to describe the world's languages, explain how language is produced and comprehended in human communication, how the ability to do this develops typically and atypically in relation to neural underpinnings, and how human language differs from other species' mediums for communication. Staff employ a range of experimental and computational methods beyond behavioural experiments, including EEG, fMRI, eye-tracking, corpus research, and Bayesian modelling. A key goal is to exploit corpus data, modelling and other computational methods in the service of theory development.

Nevins leads two large consortia of researchers across 10 institutions on under-studied languages investigating what rules are possible for mapping external manifestation of language to underlying structures. **Abels** together with collaborators at Edinburgh and QMUL uses artificial language learning to uncover universals in the noun phrase.

D. Sensory systems and therapies

Research in this theme brings together expertise in audition, vision and cognition to transform understanding of the mechanisms underlying function and dysfunction in sensory systems, and develop and validate new therapeutic approaches in areas ranging from stem cells to neuroprosthetics. Key **goals identified in REF2014** included (i) the new purpose-built MEH-IoO facility and investment in and expansion of informatics capability (described above); (ii) to build an

integrated programme of translational research applied to visual impairment and hearing loss; and (iii) develop novel approaches and technologies to interface with sensory systems. Achievements against these goals are described below.

Strategic achievements in the REF period

D1. Research in the field of **ophthalmology** spans fundamental biological science and vision research, through to translation into ophthalmology and clinical medicine (**Gazzard** Impact Case Study).

Research in development, ageing and disease harnesses genomics (e.g., Genomics England, UKBB) and transcriptomics (bioinformatics), alongside in vitro disease modelling using patient derived iPSC and organoid differentiation technologies, cell, molecular and vascular biology and biochemistry, ASO and small molecule therapies, and transplantation, to understand the pathways involved and develop better treatments and interventions for vision loss caused by defective development, childhood or early onset disease, and the effects of ageing. Research in regenerative medicine employs gene and cell therapies, physical (engineering) and pharmaceutical and biological interventions to promote healthy eyesight and improve outcomes for individuals with eye diseases. In visual function and integrative epidemiology, we investigate new ways to assess vision (including psychophysics) and combine imaging, informatics, and machine learning with epidemiology and genetics, to develop new approaches to healthcare delivery.

We have built a bespoke adaptive optics scanning laser ophthalmoscopy (AOSLO) imaging platform to investigate the relationship between retinal structure and function, at a cellular level. This technology is unique in the UK, and enables researchers to investigate genotype-phenotype correlations and perform longitudinal assessment to understand the natural history of disease. We have also established the Brian Mercer patient iPSC bank to facilitate translation.

Engagement with industry is extensive. There has been continued MRC DPFS success, with **Moss/J. Greenwood** (£4.9M) winning an award to conduct clinical trials into the use of a humanised monoclonal antibody (LRG1) to treat AMD, and resulting in a spin-out company (UCLB investment, PanAngium); **Daniels** (£1.9M) won a similar award for a phase I/II clinical trial of RAFT for aniridia related keratopathy; **Cordeiro** (£1.7M) was awarded a WT translational award for imaging techniques to detect apoptosing retinal cells. Substantial biotechnology collaborations include Apollo Therapeutics (**Limb**, £1M), ProqR Therapeutics (**Hardcastle**, **Davidson**, **Cheetham**, £1.5M) for developing ASO therapies for corneal and retinal diseases, and Gyroscope Therapeutics for gene therapy candidates for AMD (**Shima**, £322K). **Bainbridge** jointly won the Antonio Champalimaud Vison Award (€1M) for the landmark development of gene therapy for a rare genetic retinal disease. **Keane** collaborates with Birmingham through the INSIGHT program (Health Data Research Hub for Eye Health; HDRUK award).

D2. Multidisciplinary research on **hearing and deafness** moves from genomics, through cell and molecular biology, neurophysiology and computation to human sensory perception, audiology and ENT based clinical trials. In partnership with the RNTNEH this constitutes the UK's largest single grouping of audio-vestibular discovery and clinical scientists.

Research approaches combine molecular genetics and genomics for disease gene identification, in vitro disease modelling, and use of animal models to study development, normal function and disease; in vivo/awake systems neuroscience (including Neuropixels, optogenetics) and computational neuroscience (including AI), and human studies using EEG, pupillometry, psychophysics and audiometry; cell and matrix combinations for therapy, de novo design of polymers and gels and biomimicry, health data science and health economics, and the development and execution of clinical trials. Research excellence and the goal of translation and impact is evidenced by the award of a new BRC theme in Deafness and Hearing Problems (**Schilder**, **Dawson**, **Gale**, **Linden**, **Saeed,** £2.7M), facilitating infrastructural support for bioinformatics, acoustics, electronics and imaging. Facilities include light and electron microscopy (**Gale**, BBSRC, £380K for Zeiss 880); multiple purpose-built booths for human auditory testing, enhanced with the award of a 64-channel mobile EEG system (**Chait**, £120k); a modern cell-molecular biology laboratory optimized for shared use by multiple labs; and facilities for in vivo and behavioural experiments in animals.

Project collaborations with other centres worldwide include the World Hearing Centre in Poland (**Keating**) and Horizon 2020 collaborations in France, Denmark and Germany (**Chait**,

Marquardt). Major translational research advances include: Phase I and II trials successfully completed in REGAIN, a first-in-human drug trial to treat hearing loss (**Schilder**, **Saeed**, £1.2M); and EVOTION (**Bamiou**, €5.4M), a multicentre collaboration that has recruited >1000 patients and collected >33M real time datapoints from hearing aids and mobile phone apps, providing a new platform for policy-making on hearing loss and aids. **Birchall** is developing a soft robotic total laryngeal replacement, and with **Mehrban** developed novel biomaterials for clinical application. Many other industrial collaborations have also emerged over this period including work with Cochlear Ltd, GSK, Takeda, Autifony Therapeutics and Audion Therapeutics.

Over the next 5 years UCL will invest in this area by expanding and refurbishing the Ear Institute site, the freehold of which has been purchased for £6M.

D3. Research in **speech, hearing and phonetic sciences** includes the basic science behind human vocal communication together with investigations into the production and perception of spoken language. Staff study mechanisms of vocal learning and paralinguistic and extralinguistic influences on speech form, and how the communication of linguistically-coded information varies across speakers, ages, impairments and listening conditions.

Key platforms/infrastructure include equipment for capturing speech perception and production behaviour; neuroimaging technologies such as EEG, fMRI, real-time magnetic resonance imaging (rtMRI), and functional near-infrared spectroscopy (fNIRS, funded by WT); TMS; speech corpus collection and analysis; computational modelling of variation in speech production and speech acoustics; machine learning and speech signal processing.

2. People	

2.1 Staff

To ensure the continued vitality, sustainability and succession planning of research groups, FBS has committed considerable resources since 2014 to recruitment and development of permanent staff. In total 58 (52.7 FTE) new academic staff members have been appointed, including 16 new lecturers, 24 associate professors, and 18 at professorial level. Total staffing has increased by 29% on a like-for-like basis since REF2014. We have prioritised ECRs, including 57 that meet the REF definition of ECR status in this submission.

Our **recruitment strategy** comprises two main components. First, new UCL-funded positions, often associated with education initiatives, enable recruitment of outstanding staff in open competition. Secondly, we encourage, retain and integrate as many of the >600 ECRs as possible via fellowship awards of all kinds, to enhance their development and the vitality of their research groups. For example, in 2019 UoA4 ECRs applied for 193 fellowships. Where appropriate we provide institutional resources to support these applications as a major part of investing in the human capital that underpins the research environment, including bridging funds for ECRs between contracts when follow-on grants are secured (for example, the annual P&LS budget for this is ~£115K). The ablest of these researchers move on to more senior fellowships and UCL-funded posts, with proleptic appointments supporting retention. As one indicator of the success of this strategy, 6 prestigious UKRI Future Leaders Fellowships have been awarded to UoA4 staff since their launch in 2019, with substantial UoA support including tapered salary, commitment to an open-ended position at the end of the fellowship, and appropriate research infrastructure.

Generous start-up funds are provided to enable new staff to set up their research (for instance, research assistant funds for **Melis** to establish collaborations with London Zoo, and funds for **Singmann** to purchase GPU clusters for machine learning), and care is taken to limit teaching and tutorial loads during probation. Staff recruited as lecturers since 2014 have secured significant grant support (e.g., **Gould**, NIHR £1.4M; **Mason**, MRC £700K).

2.1.1 Major recruitments. Recruitments during the REF period have ensured sustainability of all major research areas.

The UKDRI award has enabled the recruitment of key group leaders in **neurodegenerative disease**. **Duff's** programme studies the causes and consequences of tau pathology propagation and the basis of selective cellular vulnerability. **Hong** investigates the immune basis of region-specific vulnerability in neurodegenerative diseases and the role of microglia in circuit-specific function and behaviour. **Busche** (awarded a UKRI Future Leaders Fellowship, £1.2M) studies

disruption of functional connectivity in neurodegeneration. **Frigerio** uses single cell genomic technologies to investigate alterations associated with AD and resilience mechanisms at cellular and genome-wide resolution. **Bartels**' research elucidates the cellular mechanisms responsible for triggering the denaturation of alpha-synuclein (aSyn) into abnormal aggregation in neurons, as observed in DLB, PD and Multiple System Atrophy. **Wiseman** leads on the development of innovative animal models for dementia research and also investigates the mechanisms driving the pathogenesis of AD associated with Down syndrome.

Within the IoN, significant new appointments include **Bates** (FRS), who founded the Huntington's Disease Centre bringing expertise in understanding the molecular basis of HD (pathogenic mechanism, mouse models of HD, therapeutic target validation and preclinical testing), and **Weil** who brings expertise in imaging and behavioural markers of progression in DLB. The **prion diseases** group has been boosted by the appointment of **Bieschke** from Washington University who brings expertise in structural biology. Future research in **neuromuscular disease** has been secured by major appointments. **Schiavo** focuses on the mechanisms of action of bacterial neurotoxins and their exploitation as tools to study signaling endosomes and axonal transport. **Brownstone** undertakes biophysical and behavioural analysis of spinal cord circuitry in a research program that aims to identify new strategies to improve movement in people with neurological disorders by studying neural circuits in the mouse brain stem and spinal cord. **Whiting** and **Fish** significantly enhance our capacity in drug discovery and development: **Whiting** leads a team of neurobiologists, pharmacologists and medicinal chemists at the DDI, developing new therapeutic approaches for dementias and neurodegenerative diseases, and **Fish** is a medicinal chemist identifying new small molecule chemical probes for epigenetic drug targets.

Major appointments in **epilepsy** include **Lignani** with expertise in the development and application of genome therapy using CRISPR-Cas9 technology; **Jepson** is an expert in drosophila models for the study of paroxystic brain disorders; **Wykes**' expertise is in the elucidation of seizure mechanisms using novel graphene electrodes; **Magloire** brings expertise in optogenetics to understand seizure mechanisms; and **Balestrini** was recruited with expertise specifically in cortical excitability and TMS. In **clinical and movement neuroscience** a major appointment is **Spinazzola**, strengthening research on mitochondrial function and dysfunction.

Institutional capacity-building investment has enabled major appointments in **clinical and epidemiological psychiatry**. **Howard** brings expertise in clinical trials and strengthens translational work in old age psychiatry. **Stone** was recruited to lead palliative care research with an emphasis on prediction. **David's** research interests include neuropsychiatry, medically unexplained syndromes and neuroimaging, as well as an innovative program on insight in schizophrenia and how it relates to treatment compliance and decision-making capacity. As noted previously, his appointment as Director of the IoMH is a major investment by UCL in this area. **Kuchenbaeker** was appointed to lead on statistical genetics with strong links with the UCL Genetics Institute. **Huys** is a psychiatrist appointed to enhance the translational impact of computational neuroscience in mental illness. **Totsika** strengthens work on mental health in intellectual disability.

Major appointments in **clinical, educational and health psychology** strengthen the following four research areas. First, several appointments ensure continued leadership in understanding mechanisms that cause and maintain the development of common mental health problems. **Steinbeis** brings expertise in understanding how socio-affective skills and behaviours change over development. **Pingault** was recruited with expertise specifically in studying influences of genetic and environmental early risk factors (e.g., bullying victimisation, family adversity) on a variety of mental health outcomes. **Gutman's** work investigates mental health trajectories in early life, with a focus on risk and resilience among minority ethnic young people. Second, several new appointments are aimed at developing new interventions to effect behaviour change to tackle key societal challenges. **Chadwick** contributes expertise on programmes to reduce childhood obesity**. Das** takes a neuropharmacological approach to reducing trauma symptoms and maladaptive behaviours such as smoking, heavy drinking and binge eating. Third, appointments address the need better to understand and treat severe mental ill health, for example, psychosis and bipolar disorder. **Bell** focuses on the cognitive neuropsychology of psychosis. **Fornells-Anbrojo** works on interpersonal processes in paranoia, and is a key figure in the development of novel virtual-reality-based treatments for psychosis. **Shaikh** investigates psychological and social processes that cause and maintain psychosis. **Mason** uses neuroimaging to better understand the mechanisms of

psychological interventions such as CBT and to improve their efficacy. Fourth, two new appointments are in the area of business psychology. **Ahmetoglu** is an expert on personality, creativity and business success, with a focus on entrepreneurship, and **Tsivrikos** seeks to elucidate how social psychology processes shape business organisations and impact on their effectiveness. All of these new recruits bring skills that will facilitate collaborations across the Faculty and will make important contributions to the IoMH.

New appointments in **human neuroimaging and cognitive neuroscience** include **de Martino** who brings expertise in the neural basis of decision making; **Fleming**, whose research programme is in metacognition; **Kok**, with a programme in visual neuroscience; **Hauser**, adding major strength in computational neuropsychiatry; **Lambert**, who brings a research programme in neuroimaging methods; **Makin**, whose expertise is in brain reorganization and plasticity; and **Bach** who studies the role of emotion in behaviour.

Capacity-building early-career recruitments in **behavioural and cognitive sciences** have been made in several domains, including **L. Harris** who investigates how social cognition is organised, **Dekker** and **Cardin** who study how behaviour emerges during development and is shaped by the way we communicate, and **Raihani** and **Melis** with expertise in how evolution has shaped behaviour and can help us understand it. **Mehta** brings new approaches to understanding the biological bases of complex behaviours, including how hormonal mechanisms moderate human cognition, and **Saleem** studies how sensory signals are moderated by cognitive signals in rodent brains.

Strategic appointments in **language and cognition** have created new capacity in cohort studies, typical and atypical language development, with **Norbury** bringing expertise in child language learning and **Taylor** enhancing strength in reading and neuroimaging research. Increasingly theoretical **linguistics** employs experimental and computational methods and strategic appointments have aimed to strengthen skills in these areas. **Chow** is a psycholinguist who employs both behavioural and electrophysiological techniques to examine the representations and processing mechanisms that underlie real-time language comprehension. **White** brings expertise in computational modelling of the learning of phonological patterns.

Demonstrating their support for DCAL, UCL recruited 3 new staff: **Cormier**, a sign language linguist and expert in corpus linguistics, leads a group developing the first ever corpus for British Sign Language and is part of a large consortium looking at how sign-language use can reveal word-order universals; **Cardin**, examining neural plasticity in deaf adults; and **Kyle**, conducting longitudinal studies of literacy development in deaf children. We have also strengthened our research in **hearing and deafness** with the recruitment of **Shekhawat** and **Cooper**, who bring expertise in translational research on therapies for hearing impairment in children and tinnitus in adults. In **speech, hearing and phonetic sciences** two major recruitments have been made: **McGettigan**, bringing expertise in the neural and behavioural correlates of human vocal communication, and **Carignan**, an expert in language production and oral articulation.

Major appointments in **ophthalmology** include **Eden** who investigates the regulation of membrane contact sites and their role in lipid transport and disease prevention, and **MacDonald** who uses zebrafish to study glial specification and the consequences of glial loss on neuronal function and structure.

2.1.2 Career Development, Mentoring and Appraisal. Attention to developing research excellence marks our policies at all levels, including annual staff appraisal and objective-setting. UCL fully supports the principles of the RCUK *Concordat to Support the Career Development of Researchers*. All parts of UoA4 have dedicated programmes for ECR development which are embedded in their Athena SWAN (AS) Schemes, and aligned with the dedicated programme for ECRs run by UCL's HR Organisational Development (OD) team.

The development of an international research profile is the expected norm and a key feature of mentoring and staff review during probation. This policy is also implemented through research excellence as a major criterion for staff recruitment and promotion; attention to staff development in the strategy for establishing new research programmes; and use of resources for infrastructure developments to support advanced research.

During the REF period **Bates** provided academic leadership for Doctoral Training and ECR staff with a full-time manager appointed to coordinate initiatives across FBS. We have

comprehensive mentoring systems both for academic and research staff. Prospective mentors are provided with training through the online mentoring platform (uMentor) developed by UCL and also participate in a cross-institutional Black, Asian and Minority Ethnic (BAME) mentoring programme. Mentors are more experienced staff working in a similar area as the mentee but without direct management involvement. The SLMS Early Career Neuroscience Forum (ECNF) and FBS Early Careers Network enable ECRs (both post-doctoral and junior PIs) to meet their peers, share experience and initiate collaborations. They also provide careers advice (e.g., clinical academic careers workshops) and disseminate information regarding jobs, training, and funding opportunities. We have established a bi-annual intensive mock grant-funding panel for junior researchers with mentorship from experienced researchers, co-ordinated by the ECNF.

The ACO, which brought in £9.2M in grant funding in 2018/19, promotes, supports and develops all aspects of academic and clinical academic careers in SLMS. Their career schemes aim to give researchers working in translational science the funding, skills and personal qualities necessary to succeed in research. A highlight is the *ADAPT to Thrive series*, in which researchers share stories of failures from their career (*Festival of Failure*[3]), aiming to normalise failure and build a more resilient research community. Other schemes include *Eureka@UCL*, focused on training in translational research, and *Clinician Coders*, which helps clinical academics to develop skills in data science. As well as offering career and support development, the ACO obtains funding to enable SLMS to offer various fellowships (including MRC Skills Development Fellowships and the WT Clinical PhD programme) through the UCL Clinical Academic Training centre. Across the UoA there is effective integration of clinical and non-clinical researchers. Several research groups are led by clinicians but include non-clinical staff, and vice versa. Careful attention is paid in employment contracts and annual monitoring schemes to ensure that clinically active staff have sufficient time for scholarly work, and that there is an appropriate balance of duties.

All staff are appraised annually within the UCL Appraisal, Review and Development scheme which includes formal discussion with the Head of Department or manager, the setting of research and training goals, and planning towards progression and promotion. The scheme plays a key role in succession planning. We fully participate in UCL's sabbatical policy, which allows paid leave free from teaching and administrative duties and which is designed to enable staff to maintain a high calibre of research, scholarship, teaching and innovation. For example, staff have taken sabbaticals at the University of Sydney (**Killaspy**) and Stanford (**Sagoo**).

To ensure that we are aware of any staff concerns, and to assist in the design of support mechanisms, UCL ran staff surveys in 2015 and 2017. FBS created and implemented detailed Action Plans following both surveys.

2.1.3 Staff training. All staff are invited to participate in a wide variety of training schemes which enhance the skills of senior staff and prepare ECRs for careers as independent researchers or for other paths (scientific writing, grant preparation). Fair recruitment training is compulsory for serving on interview panels, and PhD supervisor training for being a primary or secondary PhD supervisor. 46 staff have participated in the *Examining Doctorates* programme and 109 in the *Effective Supervision* course. Across the whole Faculty (not just submitted staff), 285 researchers have participated in the *Introduction to Research Supervision* programme.

Staff are provided with protected time to complete 10 days per year of skills training, with access to modules across 8 themes (e.g., leadership, management, communication). Staff are encouraged to use the Researcher Development Framework (RDF) tool to enhance the knowledge, attributes and skills required for success as professional researchers. 572 research staff attended the dedicated Research Staff Development Programme or the general Professional Development Programme in 2019. Many new courses in research integrity and open science (e.g., *Reproducibility for Everyone*) have been created at both central and local levels. Across the REF period, >30 staff p.a. have participated in leadership training programmes (Women in Research, Women in Leadership, Senior Women in Leadership, Future Leaders) with notable career impacts. For example, these programmes prepared many female staff including **Linden**, **Price** and **Viding** for significant leadership roles.

[3] https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(19)32943-5/fulltext

Funds are available through the UCL Graduate School for conferences, and exchanges with other academic institutions are actively encouraged. The annual *UCL Neuroscience Symposium* brings together nearly 1000 clinical and basic researchers.

Key to diversifying the skills portfolio of ECRs is providing opportunities for training in teaching. The UCL Arena fellowship scheme (accredited by the Higher Education Academy) provides education training at different levels. In the REF period 146 staff and research students have been awarded Fellowships, including 18 Senior Fellowships.

2.1.4 Promotions. Academic and research staff are recognized and rewarded via UCL's Academic Career Framework which was comprehensively revised in 2017/18 to support every type of academic career path via a robust set of processes with clear criteria. Promotions are not contingent on the availability of grant funds but are based on ability and achievements, taking full heed of personal circumstances such as parenting or caring responsibilities, part-time working, ill-health and disability.

Importantly, to address EDI concerns, Heads of Department annually consider all staff against the promotion criteria, not just those who put themselves forward. Since 2014 the ACF has explicitly recognised contributions to open science, incorporating UCL's commitments as a DoRA signatory. In the REF period 111 staff have been promoted to senior lecturer/reader/associate professor/principal research fellow and 106 to professor/professorial research fellow.

2.2 Research students

Postgraduate training is a key component of our research and scholarly activity. FBS hosts students in MRes, PhD, and Professional Doctorate programmes. In total 1493 postgraduate research (PGR) students enrolled in the REF period. The total number of PGR students increased by 17% from 802 in 2014 to 940 in 2020. The number of doctorates awarded annually increased from 187 in 2013/14 to 215 in 2018/19, and 1182 were awarded in total in the REF period.

Our commitment to doctoral research training is delivered through initiatives on recruitment, programme development, progress monitoring, equality and diversity initiatives, and integration into the research culture. The success of these is confirmed by the latest (2019) Postgraduate Research Experience Survey (PRES), with overall satisfaction at 84%.

2.2.1 Recruitment. Recruitment to PhD training is based on broad marketing (mainly digital), UCL's reputation, and active staff engagement with other HEIs, third sector organisations, and industry. We organise open days for prospective PhD and MRes students with representatives from all PhD programmes. Selection processes are criterion-based and geared to ensuring equality and diversity (e.g., decisions are taken by expert panels).

Most programmes are extremely competitive. For instance, the LWENC's programme in neurodegeneration consistently receives 200 applications for the 3-4 funded places per year; successful applicants have a mix of clinical and non-clinical backgrounds and over 95% have first class degrees or international equivalents. The WT Mental Health Science programme received >400 applications for 6 funded places in its first year, with a large proportion from BAME backgrounds, and all successful applicants had first class degrees or equivalents. The Doctorate in Educational and Child Psychology generally receives >350 applications for 16 places, and the Doctorate in Clinical Psychology programme, the most competitive in the UK, consistently receives around 1400 applications for the 53 funded positions.

2.2.2 Current programs. UCL offers a portfolio of structured 3- and (mostly) 4-year PhD programmes and we have been successful in obtaining consistent funding through UCL's MRC, BBSRC, ESRC, EPSRC and WT Doctoral Training Programmes (DTPs). Total studentship funding in the REF period has been over £12.5M.

- The **UCL-Birkbeck MRC programme** is the largest MRC DTP in the UK, funding ~8 UoA4 students p.a. on 4-year studentships, National Productivity Investment Fund and MRC iCASE studentships; the latter are based on joint projects with industrial partners, including a wide range of large (e.g., GSK, Astra Zeneca) and small-medium enterprises across four major streams in disease mechanisms, experimental medicine, neuroscience and mental health, and development;

- UCL is the lead partner (with Birkbeck, London School of Hygiene and Tropical Medicine, SOAS, and UEL) in the ESRC-funded **UCL, Bloomsbury and East London Doctoral Training Partnership** (UBEL), providing >40 studentships annually in areas spanning the social sciences. Its Psychology and Linguistics pathways fund ~4 UoA4 studentships p.a. A new Mental Health theme has been created within the DTP, funding 12 students across all partners;
- The **UCL Wellcome 4-year PhD in Mental Health Science** (**Roiser**, £5.7M), funded in 2019, is the first of its kind in the UK. It is based in the IoMH and will recruit 6 students p.a. from 2020-2024;
- The **London Interdisciplinary Biosciences Consortium** is a cross-institutional BBSRC-funded DTC (£5.4M, the largest in the UK) that funds ~2 UoA4 students p.a. on 4-year studentships;
- The **Ecological Brain** programme is funded by the Leverhulme Trust (**Vigliocco**, £1M) and provides 5 studentships p.a.;
- The **UCL WT PhD Programme for Clinicians** (**Rees**, £5.4M) funds 5 studentships p.a. across SLMS of which on average 1 p.a. is to a UoA4 student;
- The **UCL WT Neuroscience programme** (intakes 2013-18) allocated ~3 awards p.a. to UoA4 students and many other students on the programme completed their Y1 rotations in UoA4 research groups;
- The **AHRC London Arts and Humanities Partnership** (LAHP), a consortium of 8 institutions, funds 1-2 Linguistics students annually;
- **LWENC** runs a 4-year PhD programme (3-4 p.a.) funded by the Wolfson Foundation with £2M support from Eisai Pharmaceuticals;
- UCL has a doctoral partnership with the **Max Planck Society**. The joint Computational Psychiatry Unit accepts 2-3 students p.a. and also participates in the multi-institution Max Planck School of Cognition consortium (total 17 students/year);
- UCL runs PhD studentship programmes to enhance collaboration with industry or third sector organisations. **IMPACT** studentships involve collaborations with industry or third sector organisations, with UCL providing an element of matched funding. **SLMS Grand Challenge** studentships are co-funded by UCL and the BRC. Studentships funded through these schemes have involved collaborations with funders from the pharmaceutical (AstraZeneca, GSK, Eisai, Merck), manufacturing (Philips, Research in Motion, Toyota), retail (dunnhumby), and other sectors;
- FBS runs a **UCL-National Institute of Mental Health** (NIMH) 4 year joint programme in neuroscience (2 p.a.);
- A PhD programme has been established with Santen Pharmaceutical (**Ohnuma**, £1.7M) that has supported several projects.

In addition to students on research doctorates, a large number are registered on professional training doctorates. In conducting projects at the cutting-edge of their topic areas, many of which are collaborative and interdisciplinary, these students make a considerable contribution to the research culture. The **Doctorate in Clinical Psychology** programme (~60 p.a.) combines professional clinical training with comprehensive research training in the largest programme in Europe; the **Doctorate in Educational and Child Psychology** (~16 p.a.) is accredited by the BPS as a programme of initial professional training in educational psychology; the 4-year part-time CPD **Doctorate in Educational Psychology** (~16 p.a.) provides doctoral level research training for experienced educational psychologists holding masters-level qualifications; and the 4-year **Doctorate in Child and Adolescent Psychotherapy** programme (~15 p.a.) provides intensive clinical training for those wanting to work as psychotherapists in child and adolescent mental health services (CAMHS).

Lastly, MRes programmes emphasize research training and provide strong recruitment to further research degree programmes. Students spend at least 6 out of 12 months exclusively on a major research project. We have taken several steps towards integrating MRes students into the research community, for example by including them in the *Postgraduate Research Poster Symposium* organised yearly (see below).

2.2.3 Sustainable doctoral training programmes. Specific governance processes, reviewed regularly, are in place to ensure that our doctoral training is effective and sustainable. Individual DTPs supplement these general resources with specific support of their own and cohort building.

All research students are supported throughout their PhD by the **UCL Doctoral School**, which monitors student progress and ensures high quality supervision and training. Each of the units in this submission has a Departmental Graduate Tutor (DGT) responsible for ensuring fair and equitable student recruitment, appropriate supervision, progress from MPhil to PhD registration, and thesis submission. Tutors also advise students about how to access additional resources that may be necessary for their research and provide support if they encounter difficulties. All students are allocated to an experienced principal supervisor, while subsidiary supervisors have specific expertise relevant to the project. Academic and research staff are required to attend a course on PhD supervision before being permitted to supervise and must act as a subsidiary supervisor before progressing to primary supervisor. Across FBS, the number of research students per full-time academic staff member is currently 3.9 (2019), up from 2.9 in 2014.

We have made active efforts to increase academic staff involvement in PhD supervision. For instance, from the start of the 2019/20 academic year all newly enrolled PhD students are supervised by Thesis Committees (TC) designed to support the student and principal supervisor. Each TC consists of at least two members of staff and includes the subsidiary supervisor. The DGT can also be part of the TC, as can the principal supervisor (if the student agrees). The TC is chaired by the subsidiary supervisor and meets with the student at least 6 times over the course of a 3-year PhD programme. TCs also oversee the upgrade. We expect that the introduction of TCs will improve the student experience and facilitate early detection of any issues or problems. Participating in TCs allows ECRs introductory exposure to doctoral supervision, and provides a formal role for external collaborators (industry supervisors, national and international collaborators).

2.2.4 Career development and support. Considerable emphasis is placed on careers guidance both via the Doctoral School and the student's research group. The success of these mechanisms is confirmed by first destination data: of PhD students graduating in 2016-17, 95% went on to full- or part-time employment, and 4% to further study, 86% were in graduate employment, and the average starting salary was ~£45K. For professional doctorate students graduating in 2016/17, 100% went on to full- or part-time employment, 95% were in graduate employment, and the average starting salary was ~£37K. For MRes students graduating in 2016/2017, 45% went on to full- or part-time employment, 31% enrolled in further study, 100% of those who work were in graduate employment, and these students had an average starting salary of ~£32K.

All students are expected to take advantage of the Doctoral Skills Development Programme and are required to participate in this programme and/or appropriate departmental courses for a period equivalent to 10 days per year. There are over 220 different courses across the full range of skill domains defined by the Researcher Development Framework. Training courses and activities are assigned a points value (1 point = 1 half day training) and students are expected to accumulate 60 training points over 3 years, or 80 points over 4 years. Students in the 2015/2016 entry cohort averaged 54 points.

As with staff, training in teaching (via the UCL Arena One scheme) is an important element of skills development for doctoral students. In the REF period 780 students have attended workshops in this scheme and 95 the more advanced Teaching Associate Programme.

The COVID-19 pandemic and the temporary closure of non-essential research facilities and laboratories in March 2020 created major challenges for the UoA's doctoral researchers. To support all PhD students, UCL rapidly implemented several measures to ensure continuity of supervision, support, training, and funding throughout the period of lab closure and beyond. These measures include: the UCL Stipend Extension Scheme to support final-year funded students in submitting their thesis in a timely manner, by underwriting funding at the agreed minimum London UKRI rate for up to 3 months and allowing Departments/Supervisors to top-up extensions for longer periods from their own funding sources; provision of 200 free places for online bespoke training for biomedical PhD students in computing and statistical methods, including artificial intelligence (SysMic); and FBS is providing £7,500 to support doctoral students who have acquired additional caring responsibilities during the pandemic, such as home schooling or caring for an elderly or other dependant.

2.2.5 Progress monitoring. Progress is monitored using the online Research Student Log. This documents academic progression and skills development training and reflects a dialogue between students and principal and subsidiary supervisors. It allows students to record and reflect on their review meetings (including important milestones such as the MPhil to PhD upgrade) plus discussions on academic, generic and transferable skills training. Research students regularly assess and plan their skills training needs in discussion with their supervisory team using the skills self-assessment tool in the Research Student Log. Meetings of the Thesis Committee are also recorded in the Research Log.

Of all FT PhD students on three-year programmes starting in 2013, 185/222 (83%) completed their doctorates within the prescribed 4 year period. Of all PT PhD students starting in 2011, 22/32 (67%) submitted within the prescribed 7 year period. We anticipate improvement in this figure as not all the mechanisms described above were in place at the outset of this period. Special systems have been established to support part-time PhD students, many of whom are either clinicians or research assistants. Work plans are scrutinised by DGTs to ensure that candidates are given adequate time and facilities for their research and not disadvantaged by competing responsibilities.

2.2.6 Integration into research culture. The majority of doctoral students are involved in collaborative, often interdisciplinary, projects and affiliated with specific research groups within the UoA units. They therefore participate actively in the research programmes of these groups: attending research planning meetings, presenting their work, contributing to publications, and attending conferences in the same way as other ECRs. In addition, specific mechanisms are in place to ensure effective integration of students into the research culture and to prepare them for scholarly careers.

Students are encouraged to give presentations at national and international research conferences, supported by funds from the Doctoral School and individual research groups. Typically, students present at one or two national and one overseas conference during their training. A three-day Postgraduate Psychology conference is held at Cumberland Lodge every year, organised by PhD students themselves, providing an opportunity for intensive exchange with researchers outside the individual student's research group.

In addition to institutional research transparency and integrity training offered by the Doctoral School and OD, local training courses have been developed to enhance knowledge and practice in ethics, data management, research misconduct, and bullying and harassment. For example, the IoN offers a 3 month *Research Integrity and Governance* module.

FBS organises an annual *Postgraduate Research Poster Symposium*, which includes short oral presentations and poster presentations and aims to offer PG students the opportunity to present their research and meet with other students and staff. There are also prizes for both short presentations and posters judged by senior academics within FBS.

Individual departments supplement Faculty-wide mechanisms with a broad range of more specific training activities. For instance, UCL Linguistics leads a consortium of 8 universities in organising an *Advanced Core Training in Linguistics* (ACTL) graduate programme which holds advanced training events (weekly classes and summer schools) for Linguistics PhD students from across the UK. All the departments in this UoA also run regular research seminar programmes at which students present their work.

Funding is also available from the Doctoral School to learn new techniques and/or carry out research over periods of a few weeks to a maximum (exceptionally) of one year in an overseas laboratory. During the REF period >25 students have received funds allowing them, for example, to gain neuroimaging skills (Laval University of Québec, Canada). Placements with industry, Government Departments, and charities are also encouraged. These help broaden students' research experience and provide a valuable commercial and policy context for their research. Examples include work with the National Deaf Children's Society to develop an intervention programme for parents of deaf children, and with the Kosovo Association of the Deaf and the Office of the Prime Minister of Kosovo to produce the first dictionary of sign language in Kosovo. The annual *UCL Neuroscience Symposium* provides a forum for PhD students to present their research via posters to the academic community, as do many more focussed events such as the annual Queen Square graduate symposium.

2.3 Promoting equality and diversity

Effecting improvements in the equality and diversity profiles at all levels in this submission (including staff and research students) has been a key priority for enhancing the vitality and sustainability of the research environment. Here we summarise progress in advancing Equality, Diversity and Inclusion (EDI) since REF2014, consider these issues in relation to the preparation of this submission, highlight continuing challenges, and describe policies and mechanisms to address these challenges and further enhance EDI in this UoA.

The AS scheme for promoting gender equality across the HEI sector has been the main foundation for our policies and initiatives on EDI. AS Self-Assessment Teams have been established in all units of this submission. In recognition of the importance of EDI, AS teams are represented on the senior leadership and Executive bodies of all participating units, and leaders within units play active roles in AS teams. Division/Institute Directors have EDI targets explicitly set in their appraisals. In addition to core EDI activities, AS teams have led initiatives to combat harassment and bullying, to disseminate a culture of family-friendly and flexible working practices, including organisation of meetings in core working hours, and respect for parental child caring duties.

All major units within this submission have obtained AS awards during the REF period. These include 2 Silver awards (P&LS, first awarded 2013, renewed 2017, further renewal submitted Nov 2020, and IoN, first awarded 2015, renewed 2020), and 3 Bronze (DoP, IoO, and EI). To build on these awards, we have funded and appointed a Faculty AS co-ordinator and have dedicated professional services support for these activities in every Division/Institute.

2.3.1 Staff and student profile. The staff population in UoA4 is 39% female, ethnically diverse (11% BAME), and international (27% EU, 19% non-EU); 4% have a disability and 8% declare as LGBT+. After the 25-34 range (8%) the age distribution is age 35-44: 33%; age 45-54: 31%; age 55-64: 24%. The 'leaky pipeline' for gender is evident in the decrease in the proportion of female staff from Grade 8 (47%) to Grade 10 (33%). On the other hand the proportion of BAME staff in the submission is similar at Grade 8 (13%) and Grade 10 (11%).

Detailed analysis of the Faculty's entire HESA2/3 staff profile in 2013 and 2020 provides extensive evidence that our EDI work is bringing about significant change. The proportion of female staff increased from 45% in 2013 to 50% in 2020 and the proportion of white staff decreased from 80% to 72%. Between 2013 and 2020, the percentage of BAME staff at Grades 9/10 increased from 10% to 11% and at Grades 7/8 from 18% to 20%. At all levels we have made progress towards 50:50 gender diversity: in 2020, 49% of grade 8, 45% of grade 9, and 33% of grade 10 staff were women, compared with, respectively, 46%, 41%, and 30% in 2013.

Promotions data provide further evidence of the sustained impact of our EDI strategy. Of the 217 senior promotions noted above (§2.1.4), success rates were 77% for women and 90% for men in the period 2014/15-2016/17. For the period since 2017/18, success rates for female applicants have been transformed (women = 97%, men = 91%). Whereas 10/33 female applicants were unsuccessful in the first part of the REF period, only 2/61 were unsuccessful subsequently. The advancement of women in this submission is additionally confirmed by their increasing representation in leadership roles: across FBS, 12 of 29 Heads of Research Department are women.

The UoA4 graduate student population is 72% female and ethnically highly diverse (63% white, 37% BAME). 10% report a disability. Consistent with the trends above, the percentage of non-white PhD students increased from 25% in the 2013/14 intake to 33% in 2019/20.

2.3.2 Preparation of this submission. In line with UCL's Code of Practice, research staff were regularly updated on the independence determination and output selection processes and encouraged to contact their local REF leads with questions or concerns. All staff in the UOA undertake mandatory *Diversity in the Workplace* training and the UOA lead responsible for all final selection decisions attended face-to-face REF-specific EDI training. Outputs were nominated by eligible staff and reviewed by a total of 119 senior staff, of whom 65% were male, in line with the UoA's gender split at Grade 10 (67% male). Each output was independently reviewed by at least two assessors. The preliminary output selection in Nov 2020 was prepared using an automated method to optimize the profile thus minimizing human bias.

The Equality Impact Assessment (EIA) reveals trends consistent with the demographic data described above. Notably, fewer outputs are attributed *pro rata* to female (0.87 likelihood) than male (1.09) staff, and female HESA2 staff were less likely to meet the criteria for independence than males. Similar patterns apply to ethnicity, although it is encouraging that outputs were more likely to be attributed to BAME (1.07) than to white (0.98) HESA2 staff. We will incorporate this information into the development and implementation of our future AS action plans and, in particular, investigate whether success is correlated with any of our interventions (e.g., leadership training).

2.3.3 Actions to create and promote an inclusive environment. We have invested significant energy into promoting EDI and to ensuring that our staff have appropriate learning and development opportunities. UCL's umbrella leadership programme includes 5 routes: Emerging Leaders (for early-career BAME staff), Future Leaders, Women in Leadership, Senior Women in Leadership, and a new Inclusive Leadership programme. FBS has 33 funded places p.a. on these programmes. We have increased the visibility of role models by targeted actions. For example, P&LS achieved impact on the gender balance of its seminar speakers, reducing a >30% male-female gap in 2014/15 to zero since 2017/18.

172 staff in the UoA have completed UCL's mandatory *Unconscious Bias* training, which is embedded into the induction process, 108 have completed *Taking The Lead* training, equipping senior leaders with the skills to address bullying and harassment, and 26 *Where Do You Draw The Line* training workshops have been run for FBS staff. This is a harassment prevention approach collaboratively developed by UCL, Cambridge, Manchester and Oxford. In 2019/20 we piloted a bespoke training workshop on racialised implicit bias and following positive feedback are rolling this out across the Faculty in 2020/21.

Inclusive Advocacy is a positive action 2-year sponsorship programme, established as part of the Race Equality Charter, which connects senior leaders (Advocates) to Grade 7 and 8 staff (Protégées) from BAME backgrounds. The senior leader's role is to proactively ensure that the protégé receives access to useful experiences and networks that will result in career advancement. Under this scheme, 10 pairs of advocates and protégés from the UoA have been sponsored. Additionally, 6 staff have been mentored under the cross-institutional *B-MEntor* scheme. Mentors of any ethnicity are paired with a BAME mentee from a different department. The main distinction between mentoring and sponsorship is that whilst a mentor may help an employee envision and plan their next position, an Advocate will leverage their social and career capital to ensure expanding developmental opportunities for the protégé.

Workload allocation models are used across FBS to inform decision-making and fairness. We have quantitatively analysed many aspects of the collected data. For example, analysis across IoN staff for 2019 showed that male (4109 half-hour units) and female (3975 units) workloads were equitable. Analysis in P&LS allowed us to monitor the workload of part-time staff and ensure that unreasonable demands, out of alignment with full-time staff, are not placed on this group. In response to 2015 data suggesting that there was a higher adjusted workload for part-time than full time staff, workload redistribution and rebalancing took place and led to a measurable decrease in workload for PT staff.

We have investigated the recruitment of research students for competitive studentships in the UoA, and found evidence for unconscious racial bias. Indeed, there were differences between the ratings given to applications from BAME and white candidates when names and racial identity indicators were present, which disappeared when the names were absent. In 2019/20 we introduced guidance to all PhD programmes to conduct blind reviews (where the names of the applicants are not available) and will measure the impact in 2020/21 onwards. Many other initiatives are undertaken at programme level to attract a more diverse applicant pool. For example, one PhD programme created a dedicated section on its website about diversity, advertised via UCL's BAME sabbatical officer and on the *BBStem* and *Leading Roots* websites, resulting in 50% of the applicants being non-white (~200/400). This approach to recruitment will be shared across FBS and further developed in coming years. DTPs promote diversity through a range of mechanisms. For example, the WT Mental Health programme ring-fences one place in each cohort to a BAME student.

We have committed to identifying BAME staff to become highly-trained Fair Recruitment Specialists (5 staff completed this training in 2020) and have set a target of mandating the

inclusion of these in all recruitment panels from 2020/21. Plans have been drafted to introduce mandatory attendance at stereotype awareness and diversity workshops. Building on DCAL expertise, we have launched an online course, *Deaf Awareness: Working and Communicating Well with Deaf People*, and staff contribute to the *Discover UCL Summer School for D/deaf and Hard of Hearing Students*.

2.3.4 EDI leadership. Recognition of the importance of EDI has resulted in the appointment of a Faculty Vice-Dean for EDI (**Cox**) who provides oversight and coordination and chairs the EDI Committee, which includes Faculty Leads on Gender, BAME, Disability, Religion and Belief, and LGBTQ+ Equality. Staff in the UoA are members of a number of institutional and national EDI committees and networks including: Provost's Inclusion Forum, Race Working Group (Race Equality Steering Group), Athena SWAN Psychology National Forum, LGBTQ+ Working Group (LEAG), Out@UCL, UCL Women, UCL Menopause Network, UCL Astrea, Neurodivergent Staff Network, Disability Working Group and Enable@UCL.

2.3.5 Effects of COVID-19 on EDI. We are at an early stage of monitoring data on the potential unequal effects (e.g., impact on progress towards promotion) of the pandemic across different staff groups, as a prelude to a remedial action plan to support the hardest-hit groups. For gender, however, initial data show that grant applications in 2020 fell by approximately equal amounts for female (-10%) and male (-9%) staff. The UCL COVID-19 Career Support Scheme (£0.5M) provides a short-term boost to regain lost career momentum caused by the pandemic.

3. Income, infrastructure and facilities

3.1 Income

New grants totalling £720M have been awarded, with average annual income 120% higher than over the previous REF period. Average annual income per FTE researcher is £270K, 50% higher than the equivalent figure in REF2014. Funding for research from MRC (£135M), NIHR (£88M, including BRC), WT (£142M), ESRC (£25M), EC (£51M), and industry (£32M) has shown strong growth. In total we have been supported by, amongst others, 356 NIHR, 168 WT, 53 ESRC, 163 MRC, and 99 European Commission (EC) awards. In line with our REF2014 strategy, we have seen substantial growth in awards for translational research, spread across all groups. We have been awarded 182 fellowships worth £66M, including 10 NIHR, 19 MRC, 38 WT SRF/PRF/Investigator/Sir Henry Wellcome, and 7 Royal Society fellowships. In addition to these grants, income through UCL Consultancy was £6.0M in the REF period.

3.2 Major awards

Research across the UoA has been supported by numerous major grants. We briefly describe highlights in this section.

3.2.1 Theme A: Neurodegeneration and neuroprotection. Research in **neurodegenerative disease**: Major awards include a neurogenetic therapies programme to accelerate the development of life-changing treatments (**Fox**, **Rohrer**, **Tabrizi**, **Wray**, £5M Rausing Trust), and an NIHR BRC Neurodegeneration Theme Award (**Fox** as lead, £5M) to advance therapies for dementia and related disorders. Significant awards from the CHDI Foundation (**Bates**, £5M; **Tabrizi**, £2.5M), UKDRI (**Bates**, **Tabrizi**, £1.5M) and MRC (**Bates**, **Tabrizi**, £1.3M) to validate and test therapeutic targets are complemented by a WT programme award (**Tabrizi**, **Bates**, £3.2M) to aid understanding of disease mechanisms in HD. Hardy and collaborators at Oxford, Cambridge, and the Royal Veterinary College were awarded $7M from the MJ Fox Foundation to study the variability of Parkinson's progression; a major longitudinal study (Insight 46) to detect prodromal dementia and the life course determinants of brain pathology (**Fox**, **Schott**, combined funding £11M); the MRC-funded Genetic FTD Initiative (**Rohrer**, £2.8M); a C9orf72 study in mediated neurodegeneration in FTD and ALS (**Isaacs**, €1.9M). Since 2014 £7.2M has been secured for ARUK Senior Fellowships (**Barnes**, **Lashley**, **Wray**), CHDI Foundation (**Wild**), WT (**Weil**), and MRC Clinician Scientist Fellowships (**Rohrer**, **Wild**, **Ryten**).

Prion diseases: Major funding and senior fellowships totalling £38M including awards from MRC, BBSRC, DHSC Policy Research Programme, ARUK, Alzheimer's Society, CJD Foundation, CJD Support Network; MRC has awarded 2 3-year clinical fellowships. **Collinge** and **Mead** are both NIHR Senior Investigators.

Neuroinflammation: Major funding comes from NIHR (Research Professorship to **Ciccarelli,** £1.8M), MRC (**Toosy**, £1M), EU-IMI Consortium grant (€8.8M, **Pocock** as UCL lead), Horizon 2020, Charities (Fondation Leducq, International Spinal Research Trust, UK and US MS Societies, Rosetrees Trust, Wings for Life), and WT.

Neuromuscular disease: The ARUK DDI award (**Fish**, **Whiting**) has been described previously. Other grants include a WT Strategic award (**Harris**, £3.5M); **Schiavo** is part of an Horizon 2020 Research and Innovation Programme (€15M). **Sharma** leads the UCL Integrated Academic Training programme, the largest in the UK and involving ~150 junior academics (£5M). Industrial collaborations include awards from Orphazyme (**Machado**, **Hanna**, **Greensmith**) and Lilly (**Schiavo**). An investigator-led trial is supported by the FDA Office of Orphan Products Development Grant Program (US$1.6M: **Hanna**, **Greensmith**, **Machado**). Senior fellowships include 5 WT Senior Investigator Awards (**Brownstone**, **Fisher**, **Harris**, **Schiavo** and **Ule**); two PIs were awarded the only MRC Senior Clinician Scientist Fellowships in 2018-19 (**Fratta**, **Patani**); intermediate level fellowships include an MRC Career Development Award (**Sleigh**), two MRC Intermediate Fellowships (**Pitceathly**, **Cortese**), and a senior Motor Neuron Disease Association non-clinical fellowship (**Bryson**), an ERC Senior Investigator Award (**Harris**) and an Advanced Grant (**Ule**, £1.3M).

Epilepsy: major funding and fellowship awards include: ERC advanced grants (**N. Burgess**, £2.0M; **Rothman**, £1.8M), Epilepsy Research UK fellowship (**Magloire**), MRC New Investigator Grant (**Jepson**, **Lignani**), MRC Programme Grants (**Duncan**, **Kullmann**, **Walker**), NIH Centers without Walls (**Diehl**), NIHR BRC High Impact Initiative (**Koepp**), NIHR RIGHT Programme (**Sander**), WT Principal Fellowship (**Kullmann, Rusakov**), WT Innovation (**Duncan**), and WT Strategic Award (**Jepson**, **Kullmann**, **Rothman**, **Sisodiya**, **Volinskii**, £4.1M).

Clinical and movement neuroscience: Staff have been successful in gaining fellowships, including **Gandhi** (WT Intermediate Clinical Fellowship and MRC Senior Investigator Award), **Kuppuswamy** (WT Sir Henry Dale), as well as major grants: MRC Experimental Medicine (**Schapira**, £1M) to study glucocerebrosidase mutation and personalised therapy in PD; Horizon 2020 (**Schapira**, €6M, **Schrag**, €4M) on mitochondrial involvement and developing palliative care in PD; Joint Program on Neurodegenerative Diseases (**Schapira**, €1.6M) on clinical evolution of GBA-linked PD; and NIHR programme grant (**Schrag**, £2.2M) on the development and validation of a facilitated self-management tool for PD. Major awards in 2020 include $8.4M for research into the effects of the microbiome in PD (**Schapira**), $7.5M for research on alpha-synuclein biology in PD (**Wood**) and $1.2M on single cell sequencing (**Proukakis**). Additional funders include the Brain Research Trust, MJ Fox Foundation, Parkinson's UK, and Safra Foundation. **Spinazzola** was awarded an MRC Senior Non-Clinical Fellowship (£2.2M).

3.2.2 Theme B: Mental health. **Clinical and epidemiological psychiatry**: Major funding in the REF period includes the establishment of the Mental Health Policy Research Unit (**Johnson**, NIHR, £5M). A mental health theme (£5M) was created within the BRC renewal, led by **Howard**. Palliative care research has been funded by a Marie Curie centre grant (£2.3M) with an associated grant for **Stone** (£3.2M) and a programme grant to improve care, assessment and communication at the end of life (£2M). An ERC Starting Grant for genetics of depression in diverse populations was awarded to **Kuchenbaecker** (£2.5M). NIHR have funded several large randomised trials (>£22M). The group's vitality has been supported by several senior Fellowship awards, including **Kirkbride** (Sir Henry Dale), **Hayes** and **Huntley** (WT Clinical Research Career Development), **Davies**, **Marchant**, **Moore**, **Mukadam**, and **Orgeta** (Alzheimer's Society Senior Fellowships), **Wood** (NIHR Clinical Lectureship) and **Irizar** (European Commission Marie Curie), and NIHR Senior Investigators (**Livingston**, **Howard**, **Lewis**, **King**).

Clinical, educational and health psychology: awards include NIHR Senior Investigator Awards (**Fonagy**, **Michie**), MRC Clinical Research Fellowship (**Mason**), Sir Henry Dale Fellowship (**Carlisi**, **Schoeler**), MQ Transforming Mental Health Fellowship and EC Consolidator Grant (**Pingault**), WT Collaborative Award (£2.2M), NIHR School of Public Health Research (**Michie**, £1.5M), Big Lottery Fund and DfE (**Deighton**), NIHR Programme Grant and Guideline

Development Grant (**Pilling**, £1.9M), NIHR Innovation Grant (**King**, £1.26M), ESRC, NSPCC (**McCrory**), NIHR (**Fonagy**, £1.6M), NIHR Public Health (**Scior**), EC Consolidator Grants (**Fotopoulou**, £1.6M; **Pingault**, £1.2M), EC (**Steinbeis**, £1.2M), and MRC (**Curran**, £1.6M; **Kamboj**, £470K; **Michie**, £470K; **Viding**, £700K).

Human neuroimaging and cognitive neuroscience: major awards include 2 Wellcome Centre for Human Neuroimaging renewals (£14.8M), Max Planck Centre for Computational Psychiatry and Aging (£1M), Wellcome PRFs (**Price**, **Maguire**), WT (**Maguire**, £2.4M) and further Fellowships and major awards, including WT Senior Research Fellowships (**Makin**, **McSweeney**, **Crinion**), MRC Senior Research Fellowships (**Lambert**, **Robinson**), 4 Sir Henry Dale Fellowships (**Fleming**, **De Martino**, **Hauser**, **Kok**), an NIHR Research Professorship (**Leff**), a Dorothy Hodgkin Fellowship (**White**), ERC advanced grants (**Bach**, £1.6M), 3 ERC starter grants (**Makin**, **Kok**, **Hauser**), 3 WT Collaborative awards (**N. Burgess**, with collaborators from Oxford, hosted at the Sainsbury Wellcome Centre; **Rees** with colleagues from UCL; **Barnes** with collaborators from Nottingham), a £4.5M WT Innovation award (**Rees**), and an EPSRC Collaborator award (**Lavie**, with Jaguar Land Rover and Cranfield).

3.2.3 Theme C: Understanding and influencing human behaviour. In **behavioural and cognitive sciences**, research has been funded by major UKRI awards including ESRC (**Rodd**, £540K; **Shanks**, £850K; **Vigliocco**, £530K), BBSRC (**Bendor**, £500K; **Cardin**, £240K; **Solomon**, £400K), EPSRC (**Skipper**, £390K), MRC (**Solomon**, £680K), as well as ERC (**Bendor**, £1.2M; **Spiers**, £400K; **Vigliocco**, £3.0M) and other funders including WT (**Jeffery**, Senior Investigator, £1M; **Love**, Senior Investigator £1.1M; **Sharot**, Senior Research Fellow, £1.7M), Nuffield (**Richardson**, £270K) and IARPA (**Lagnado,** £540K). New researchers have won prestigious fellowships (**Dekker**: ESRC; **Fleming**, **Saleem**: Sir Henry Dale; **Raihani**: URF).

In **language and cognition**, major awards include ESRC (Norbury, £650K), Leverhulme (Wonnacott, £320K), AHRC (Varley, £230K), Stroke Association (Varley, £200K), and in **linguistics**, significant support has been provided by funders including AHRC (**Szendroi**, £690K) and Leverhulme (**Nevins**, £330K; **Carston**, £240K).

3.2.4 Theme D: Sensory systems and therapies. **Ophthalmology**: Six investigators hold WT Investigator Awards, **Carandini** (collaborative with **Harris**, £3.6M), **Cheetham** (£1.5M), **Futter** (£1.3M), **J. Greenwood** and **Moss** (£1.7M), and **Ruhrberg** (£1.4M). **Carandini** has been a Simons Investigator since 2014. Strategic development of ECRs has been supported by fellowships from BBSRC (**MacDonald**, £960K), WT Clinical Career Development Fellowships (**Moosajee**, £1.2M; **Mahroo** £1.1M), NIHR Clinician Scientist award (**Keane**, £980K), Fight for Sight Early Career Development fellowships (**Davidson**, **Arno**), and UKRI Future Leaders Fellowships (**Davidson**, £1M, **Keane**, £1M, **Khawaja**, £1.2M). In addition to EC funding (**Rubin**, £660K), we hold substantial charity, philanthropic and UKRI funding, including **Coffey** (Oak Foundation £1.2M, Uren Foundation £2.2M, MRC £2.7M), **Pearson** (MRC £2.3M), and **Turowski** and **Sivaprasad** (RCUK GCRF £2.3M for the ORNATE India project).

Hearing and deafness: Significant EC funding has been secured, with two ERC Consolidator awards (**Albert**, £1.4M; **Bizley**, £1.5M) and major Horizon 2020 awards (**Schilder**, **Saeed**, £1.2M; **Bamiou**, €5.4M). Research has been further enhanced by two WT (**Lesica**, SRF, £1.5M; **Bizley**, Sir Henry Dale, £1.9M including renewal) and two UKRI Future Leaders Fellowships (**Andres**, £1.5M; **Keating**, £1.4M, the latter being a former Rosetrees Trust/UCL Excellence Fellow).

Speech, hearing and phonetic sciences: Major funding has been received from: ESRC (totalling £2.4M) supporting the study of speech communication changes across the lifespan (**Hazan**) and development of speech perception and measurement of listening effort (**Iverson**); WT (£1.3M) to support Avatar Therapy (**Huckvale**); Leverhulme Trust (£1.2M) including computational models of speech acquisition (**Xu**); EC (£1.2M) to support two training networks (**Hazan** and **Iverson**); and EPSRC (£1.1M) to study binaural hearing aids (**Rosen**, **Huckvale**). In addition funding for a spin-out company in fatigue management was received from ESA (€1M) using voice analysis technology developed by **Huckvale**.

3.3 Major infrastructure investments

Highlights of unit-specific investments and income, and major future developments, are reported in detail in our Research Strategy in §1.

Major Schemes:

- Development of a £280M, 17,000 m^2 translational neuroscience building for IoN and UKDRI (£41M BEIS, £29M RPIF, £60M donors);
- IoO/MEH new building £155M, including 10,000 m^2 for IoO, total cost ~£500M (£30M RPIF, £60M donors);
- Courtauld Building for the MRC Prion Unit, £30M for ~3,000 m^2;
- UKDRI Interim Hub in the Cruciform Building, £10M (£2M MRC) for 1,200 m^2 of refurbished laboratory and office space;
- £2.5M to relocate DoP to 1,500 m^2 of newly refurbished accommodation in Maple House facilitating expansion in support of the IoMH;
- £2M for fit out of Russell Square House to facilitate expansion of IoN teams.

Refurbishments:

- £1.5M for Cruciform Building refurbishment for cortical neuromics laboratory (**Carandini**, **Harris**);
- £0.7M modifications to Alexandra House for ICN;
- £0.7M for laboratory modifications (**Rothman**);
- £0.9M for a laboratory facility for studying the neural circuits for movement (**Brownstone**);
- £1M to refurbish laboratories for the ARUK DDI in the Cruciform Building;
- Several UCL Small Works Projects across the UoA.

The **SLMS Capital Equipment Fund** gives priority to proposals with cross-faculty and multidisciplinary applications. £1.4M of funds have been provided to the UoA in the REF period for equipment including eye-tracking, functional transcranial Doppler and motion capture systems. UCL is also a recipient of WT Institutional Strategic Support funding, and £1.5M has been received for equipment, bridging, recruitment start-up packages and translational pump priming. Institutional resources, often leveraging external funding, have enabled further investments in equipment and laboratory refurbishments during the REF period, including:

- Extensive upgrade of neuroimaging facilities: a new Siemens Prisma 3T MRI scanner has been installed in BUCNI (£2.3M); two further Siemens 3T scanners have been upgraded to Prisma systems (£1.1M); a Siemens 7T Terra scanner was delivered in 2019 (£8.5M), with additional funding from Siemens to develop MRI sequences and software; and a Philips 3T scanner was upgraded to an Ingenia system in 2018 (£600K, with BRC funding) with provision of a sodium quantification system;
- A magnetically shielded laboratory for pioneering Optically Pumped Magnetometry (OPM) research (WT collaborative award, £870K).

3.4 Equipment, facilities and support

Long-term institutional and funder investment has provided outstanding cost-recovered facilities for research, brought together under UCL's **Scientific Technology Platforms** initiative (e.g., genomics, imaging). A central **Research Equipment Catalogue** ensures that the fullest use of these facilities, equipment, and technician support is made across research teams. These include:

- Major facilities for neuroimaging including a Siemens Avanto 1.5T scanner, VSM MedTech MEG scanner, functional transcranial Doppler and near-infrared spectrometry systems in addition to the 5 new/upgraded MRI scanners described above. All facilities provide substantial IT, physics, radiography, and electronics support;
- A further 4 Siemens MRI scanners are available for research within NHNN, a 3T Prisma, a 3T Skyra, and two 1.5T systems, one of which is combined with a neurosurgical suite for interventional MRI projects;
- Extensive facilities for imaging and microscopy, including electron, photon, laser capture and confocal microscopes as well as specimen preparation equipment including cryo-preparation and microtomes;

- Equipment and laboratories for 3D whole-body motion capture; eye-tracking; gene sequencing; transcranial magnetic stimulation systems; frameless stereotaxy systems; equipment for capturing motor evoked potentials; an MRI-compatible EEG system;
- Extensive animal neuroscience facilities including histology and electrophysiology, specialist laboratories for research in infant vision, child development (with advanced audio-visual facilities for attachment research), neuropsychology (including an extensive range of test batteries), speech and language, and human-computer interaction, as well as numerous general-purpose testing facilities; specialised laboratories (including Faraday cages) for human electrophysiology, crossmodal attention, and motor control studies, plus patient testing suites; a wet-lab and psychophysiology suite for psychopharmacology research;
- Underpinning these research facilities is considerable investment in human resources. Technical staff (153 FTE) have increased considerably (+36%) since 2013. Other support staff (278 FTE, +27%) have also increased over the same period.

Researchers have access to 16 **UCL libraries**, including collections in all UoA4 specialties. A WT Research Resources in Medical History award enabled preservation and cataloguing of neurology archives in the Queen Square Library. A team of Site and Subject Liaison Librarians provides an enquiries service as well as information skills training for researchers (e.g., in systematic review, reference management), and supports Open Research through administration of the REF OA policy and the UCL Open Access Repository.

3.5 Research governance

UCL has a set of research governance policies, detailed in REF5a, that underpin expectations about the conduct of research. The *Code of Conduct for Research* articulates UCL's expectations and defines action to be taken if an individual is suspected or accused of research misconduct. All issues relating to confidentiality and security in the use of patient and participant data fall under UCL's Data Protection policies and the Data Protection office provides extensive training, guidance, and support.

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

4.1 Major institutional collaborations

The major national **UKDRI** collaboration on dementia, and the large-scale translational research partnership in ophthalmology between UCL and **MEH** via the **IoO**, are described in §1.

The **Sainsbury Wellcome Centre** for neural circuits and behaviour, funded by the Gatsby Charitable Foundation and the Wellcome Trust (WT), opened in 2016 and substantially strengthened UCL's research in systems-level neuroscience. Neuroscientists working in the new facility use state-of-the-art molecular and cellular biology, imaging, electrophysiology and behavioural techniques, supported by computational modelling, to investigate how brain circuits process information to create neural representations and guide behaviour. A key strength of the Centre is that it includes the Gatsby Computational Neuroscience Unit, which combines research in theoretical neuroscience and machine learning. The Centre nurtures close links with research groups in UoA4: among the 20 affiliates are **Bizley**, **Brownstone**, **N. Burgess**, **Carandini**, **Harris**, **Jeffery**, **Kullmann**, and **Linden**.

The Centre hosts a number of activities that are synergistic with FBS, including a core research base for the **International Brain Laboratory** (funded by £25M from WT and Simons Foundation), a major initiative bringing together 22 international groups of which 6 are based at UCL and 2 (**Carandini**, **Harris**) in UoA4.

The **Francis Crick Institute** is an important partnership for the UoA. Through a range of initiatives, researchers are actively developing and strengthening links between the founding partner organisations. During the assessment period, as part of the Crick-HEI Attachment Scheme there have been four group secondments (**Ule**, **Patani**, **Gandhi**, **Moosajee**) and two satellites (**Albert**, **Fish**) from UoA4. In addition, **De Strooper's** group is now established within the Crick in UCL-funded space. The presence of the UKDRI and DDI (through **Fish**) enables even greater recognition of these UoA4 institutes on a national and international scale. UoA4 contributes leadership to the Crick (**Gandhi**, Assistant Research Director; **Rees**, co-chair of the University

Academic Partnership Committee), its research staff hold joint grants with Crick Group Leaders (e.g., **Fisher** with V. Tybulewicz), are actively involved in Crick Interest Groups (**Schiavo**, **Lignani**, **Matthews**, **Andres-Miguel**) and are secondary supervisors for 13 students on the Crick PhD programme.

The **Institute of Healthcare Engineering** is a cross-institutional initiative bringing together engineers, computer scientists and health researchers to develop digital and medical technologies. Prof Geoff Parker was recruited jointly by UCL Computer Science and IoN to lead the Institute's research on the application of quantitative MRI methods to a wide range of diseases including neurological conditions.

In CAMHS, our long term partnership with the **Anna Freud National Centre for Children and Families** has flourished over the REF period. **Fonagy** is the Centre's Chief Executive and led the project to create its state-of-the-art £40M new home close to the UCL campus, facilitating the numerous research and training collaborations. It hosts many UCL professional education programmes, including at doctoral level.

UCL has launched a key international partnership with **Peking University**, supporting initial research collaborations in dementia (**Spector**) and neuroscience (**Chait**, **Fleming**, **Haggard**). The IoO is the International Strategic Partner for the newly formed International Centre for Translational Eye Research (ICTER; Poland), focusing on imaging at different levels of resolution, from single molecules to the entire architecture and function of the eye. A strategic Memorandum of Understanding (MoU) is in place with Singapore National Eye Centre (SNEC) and Singapore Eye Research Institute (SERI), principally to build on research infrastructure for AI, big data and health service related research. An MoU with the University of Electronic Sciences and Technology in China has been established to develop studentships and build a PhD student cohort in imaging and AI.

4.2 Collaborative networks and clinical trial consortia

Our extensive involvement in collaborative research networks is described in §1.6. Staff are also centrally involved in major global discovery science and clinical trial consortia. These include the International Parkinson Disease Genomics Consortium (IPDGC; **Hardy**, **Plun-Favreau**, **Ryten**, **Wood**) and the Alzheimer's Disease European Sequencing Consortium (ADES; **Hardy**); in HD, the HD-CSF, HD-Clarity (**Wild**) and Roche-sponsored Natural History Study and GENERATION HD1 phase 3 trial (**Tabrizi**); the 27-site Genetic Frontotemporal Dementia Initiative (GENFI) cohort study (**Rossor**, **Rohrer**); **Rohrer** also co-leads the FTD Prevention Initiative linking GENFI and other genetic-FTD studies around the world; the Dominantly Inherited Alzheimer Network (DIAN), DIAN-TU and Alzheimer's Disease Neuroimaging Initiative (ADNI) collaborations in AD (**Fox**); and the WT-sponsored Vision in Parkinson's initiative (**Weil**). The Alzheimer's Association Global Biomarker Standardization Consortium (GBSC), aiming to accelerate biomarker standardisation for AD and other dementias, is chaired by **Zetterberg**.

Sisodiya leads international epilepsy consortia on discovery (EpiCNV), pharmacogenetics (EpiPGX), and genetic-imaging integration (ENIGMA-Epilepsy), chairs the ILAE Task Force on Clinical Genetic Testing in the Epilepsies, and is on the steering committee of international genetics consortia (Epi25, ILAE Consortium on Complex Epilepsies). In stroke, **Werring** leads the Microbleeds International Collaborative Network (MICON), with influence on national (NICE) and international (ESO) guidelines.

The Psychiatric Genomics Consortium involves **Bramon** (leading on psychosis endophenotypes), **Kuchenbaecker** (leading on ethnic diversity within the Major Depression Collaboration, funded by ERC £2M), **Lewis**, and **McQuillin** (leading the collection and analysis of sub-phenotype data for bipolar disorder). **Foster** leads the UK Biobank Eye and Vision Consortium and part of the International Glaucoma Genetics Consortium (IGGC). IoO/MEH are major contributors to the Genomics England project, with **Webster** Clinical Interpretation Partnership lead for the Hearing and Sight domain, and the UK Inherited Retinal Dystrophy Consortium (UKIRDC; **Arno**, **Hardcastle**).

4.3 Individual collaborations

For the following sections we have taken a quantitative approach, supported by examples. Data were obtained from a comprehensive survey completed by all submitted UoA4 staff. External collaborations are supported by the award of honorary positions (including **Category C staff**). A

total of 1096 individuals, many with NHS appointments, held such positions on the census date, with 161 being at professorial level, and including world-leading researchers (e.g., C. Frith, U. Frith, R. Murray, T. Shallice, C. Sunstein).

In addition to the collaborations noted in §1.6, staff have taken part in collaborative research involving other UK (85% of staff) and international (84%) institutions, and in interdisciplinary research (60%). International collaborations are thriving as indicated by the award of 158 EU and 201 non-EU grants in the REF period. 93 members of staff (24%) have hosted visiting international researchers for a period of 12 months or more, funded by a competitive scheme from their own country.

4.4 Contribution to sustainability of the research base

The breadth of contributions is highlighted by the following aggregate metrics: 42% of staff have served on national (UKRI or similar) or international grants committees, and 40% on learned societies/professional bodies; 67% of staff have given invited keynote lectures; 57% have participated in conference organization; and 84% have examined doctorates; 98% are involved in some aspect of refereeing/peer-reviewing, while 52% of staff served on journal editorial boards, 31% in editorship positions.

Our approach to research transparency and reproducibility is detailed in §1.4. In the REF period, 40% of staff published research that reproduces key findings in their field.

4.5 Contribution to the economy and society via collaboration with industry and research users

Staff have engaged extensively with industry (44%), with many examples described above, through 72 CASE studentships, industry-sponsored research, Higher Education Innovation Fund awards (25 projects, £470K) and consultancy, and in collaborations for postgraduate research training (25%); with health and social care services (40%); and with central or local government bodies (14%). Effective collaboration with industry is corroborated by the award of 141 grants from industrial partners, with 38% of staff having sat on non-academic expert committees, and this collaboration has led to significant translation or commercialisation: 43% of staff have been involved in patents, licensing, spin-out formation, consultancy, clinical trials, or been awarded translational funding. Our Impact Case Studies provide examples of the extensive benefits of these collaborations for income generation, patient benefit, NHS cost-saving and other societal gains.

Staff make major contributions to clinical trials, with UCLH and MEH at the forefront nationally for patient recruitment. In the REF period 168 UCLH-hosted trials led by UoA4 researchers were initiated as well as 85 hosted at MEH and 126 elsewhere (e.g., C&I, NELFT), sponsored by industry (e.g., Bayer, Pfizer, Roche, Santen), charities and NIHR.

4.6 Response to the COVID-19 pandemic

Researchers and facilities in UoA4 have made major contributions to the national effort to fight the COVID-19 pandemic. **Michie** is a member of the behavioural science sub-group of the government's Scientific Advisory Group for Emergencies (Sage), and also a member of the independent Sage committee.

A total of 53 projects, of which the majority are funded or a funding application has been submitted, have ranged from public engagement to novel diagnostics and therapy delivery. Three examples are briefly described here. **Koepp** studied SARS2-CoV-2 transmission, and related morbidity and mortality, in long-term care facilities for people with chronic epilepsy and co-morbidities. The EBPU (**Deighton**, **Edbrooke-Childs**) developed two streams of dissemination activity to respond to the mental health challenges posed to children and families during the pandemic, including emerging evidence briefings (lay summaries synthesising the research literature emerging about the impact of Coronavirus on children and young people's mental health) and Research bites, short summaries of research knowledge around key themes relevant to challenges that young people have been facing during the pandemic (e.g., on supporting pupil mental health and wellbeing during the return to school). These briefings were downloaded over 2500 times between April and June 2020. Video summaries with lead authors were produced to enhance engagement and accessibility. **Ward** and **Leff** developed N-ROL (*Neuro-Rehabilitation OnLine*) as a rapid response to the reduction of in- and out-patient therapy available to patients

with acute brain injury (e.g., stroke). This charity-funded programme delivered over 2000 patient-sessions. A patient who was treated via N-ROL was featured on the BBC News at Ten.

4.7 Contribution to society via engagement with wider audiences

Staff in UoA4 (85% in total) have developed relationships with many research users, beneficiaries or audiences outside the university sector, including policy makers, patient groups, local communities, healthcare practitioners, museums, schools, and the media. These activities have included policy development, media coverage, exhibitions, open days, public lectures, and student mentoring/work placements.

4.7.1 Working with policy makers. We explicitly encourage UoA4 staff to contribute their research and expertise to a wide range of policy areas that have led to engagement with national and international policy-making bodies. For instance, **Livingston** led the *Lancet Commission on Dementia Prevention and Care,* which identified a possible 33% reduction in dementia incidence via modifiable factors such as exercise and improved hearing, leading to changes in Public Health England's middle age dementia check. **Cox** was appointed a Special Advisor to the Department of Culture, Media and Sport's select committee inquiry into Immersive and Addictive Technologies.

McCrory leads the UKRI *Adolescence, Mental Health and the Developing Mind* programme and serves as Co-Director of the UK Trauma Council, comprising national leaders in the first UK-wide platform enabling collaboration between individuals and organisations with expertise in childhood trauma producing educational materials and policy recommendations in response to national emergencies such as the pandemic and terrorism. **McCrory** and **Fonagy** are members of the *Expert Group on Early Intervention* to guide the charitable activities of HRH the Duchess of Cambridge. **Fonagy** is Senior National Clinical Advisor for Mental Health in Children and Young People at NHS England/Improvement, and in this capacity frequently advises the Secretary of State for Health, Ministers of State (both Education and Health), and has given evidence to several Select Committees (Health and Science & Technology). **Collinge** has served on Government advisory committees on prion disease at a national and international level.

UoA4 staff are also encouraged to contribute to national health policy through NICE committees and clinical guideline groups. Research carried out in UoA4 has made major contributions to a diverse range of NICE guidelines including treatments for social work interventions (**Lloyd-Evans**), hearing loss (**Costafreda**), eating disorders (**Serpell**), psychosis (**Johnson**), stroke (**Werring**), headache (**Matharu**), attachment (**Fearon**), psychosis treatment and rehabilitation (**Killapsy**, **Osborn**), and mentalization based therapy (**Fonagy**). In addition, staff have chaired or been members of guideline committees, including for brain tumours (**Brandner**), MS (**Ciccarelli**), glaucoma (**Foster**), MND (**Bloch**), and medicinal cannabis (**Pilling**). **Thompson** led the International Panel on Diagnosis of Multiple Sclerosis which recommended new diagnostic criteria that are used worldwide. **Pilling** received a Distinguished Contribution to NICE Award.

FBS hosts three national research policy units led by: **Johnson**, Director, NIHR Mental Health Policy Research Unit; **Michie**, Co-Director, NIHR Behavioural Science Policy Research Unit; and **Pilling**, Director, UCL Centre for Outcomes Research and Effectiveness.

4.7.2 Engagement with practitioners. We provide CPD for clinicians and researchers involved in neuroscience-associated healthcare, capitalizing on the opportunities that this presents to train specific groups to exploit our research. DCAL, for example, offers a suite of online deaf awareness courses targeting health professionals to help better understand the communication needs of D/deaf and hard of hearing patients. These are accredited for CPD by professional bodies including the Royal Colleges of Nursing, Physicians and General Practitioners. Our evidence-based competences for delivering behavioural support in the English Stop Smoking Services (**Michie**) have led to assessment, certification and training of 4,000 practitioners in England.

To support and encourage such engagement, we provide resources such as CPD@PaLS, a unit within P&LS that provides focused support for an extensive programme of courses predominantly for speech and language therapists, teachers and psychologists, seeking either to acquire specific skills or to update their knowledge. The topics covered relate to both adults and children with speech and language difficulties, and reflect the wide range of our research interests, including adult and paediatric dysphagia, dyspraxia, CAMHS, behavioural issues, supervision, counselling, language disorders and British Sign Language.

UoA staff working with the AFNCCF (**Fonagy**, **Edbrooke-Childs**, **McCrory**, **Midgley**) provide advanced training for ~11,000 professionals who work with young people each year. This includes over 30 different courses covering a wide range of topics from mentalization to evaluation methods, as well as the £8M DfE train-the-trainer programme of Return to Wellbeing to English schools to provide mental health awareness training to teachers as children returned from lockdown in September 2020.

Our approach deliberately encourages key individuals to seek out entirely new audiences that may benefit from our research. For example, **Walsh** applied principles of cognitive neuroscience to the challenges faced by sporting elites as a special advisor to the English Institute of Sport and Cognition Advisor to the GSK Human Performance Laboratory, a facility built to examine and promote elite performance.

4.7.3 Working with schools and education professionals. Our research on brain plasticity, cognitive enhancement and the determinants of common problems such as conduct disorder, developmental language disorder, dyslexia and dyscalculia has direct relevance to teachers in mainstream and specialist schools. UoA4 staff (e.g., **Rees**, **Dunsmuir**) have been actively engaged in bidirectional knowledge transfer with local authority services, schools and their staff (including the UCL Academy) through delivery of training and participation in curriculum design and development. Staff participate more widely by giving talks in schools and at school conferences. We have also made commissioned contributions to the review of the critical incident response to the Grenfell Tower fire by professionals working in schools (**Dunsmuir**, **Hayes**) and an evaluation of resources for schools developed with the charity Changing Faces to address stereotyping of children and young people with visible facial differences (**Dunsmuir**). The AFNCCF *Schools in Mind* information network has a membership of over 19,000 teachers and the *Mentally Healthy Schools* resource website had >100K users during the summer of 2020 (**Deighton**, **Edbrooke-Childs**).

The SCALES Study (**Norbury**) has provided data on the prevalence and persistence of language and learning difficulties from school entry, involving over 180 schools. These data have been quoted in parliamentary debate and cited in a joint report by the National Literacy Trust and the All Parliamentary Party Group on Literacy, outlining education policy initiatives to support development of reading and writing.

4.7.4 Public engagement and the media. In response to the significant interest in our research among both patients and the public, we have worked hard to develop and refine an approach ensuring the effective communication of new findings to those audiences. To that end, we work proactively both with **UCL Media Relations** and the press offices of funding organisations (e.g., MRC, WT) to ensure that publication of important findings is linked to press releases and media contacts.

We record the extensive media coverage of UoA4 research in our institutional information systems. Staff appear weekly in print and broadcast media, and during the census period have been interviewed or featured on every major news and current affairs programme, among them R4 Today, BBC News 24, Sky News, Channel 4 News, BBC Newsnight, CNN, Al Jazeera, and all major print media (e.g., Guardian, Independent, Times, Telegraph, NY Times, Reuters, Time, Wall Street Journal).

Scott (Impact Case Study) delivered the *Royal Institution Christmas Lectures* (2017) and received a CBE for services to neuroscience. HE-BCI data for 2018/19 record that 272 days of staff time were allocated to 71 public engagement events with a combined audience of >10,000 people. These activities have helped us secure new funding specifically to engage external audiences (e.g., WT public engagement awards: **Patani**, £108K for MND; **Ward**, £75K for stroke). We extensively work with patient populations to solicit their input and help focus our research questions (**Nachev**, **Price**, **Ward**) and develop novel therapeutic interventions (**Crinion**, **Lambert**, **Leff**, **Weil**). We organise public-facing events such as interactive exhibits at the Science Museum and their *Lates* program (**J. A. Greenwood**, **Richardson**, **Vigliocco**, **Vinson**), academic-corporate conferences to build bridges with industry (**Devlin**), and public talks and activities such as *Nudgestock, Pint of Science*, and *I'm a Scientist Get Me Out of Here* (**McGettigan**, **Rodd**, **Skipper**). We deliberately coordinate our external engagement activity around major (inter)national events such as the annual *Dana Brain Awareness* week.

We seek to reach diverse audiences by regularly presenting major exhibits at the *Royal Society Summer Science Exhibition* (**Barnes**, **Scott**), and by presenting our research every year for general audiences at the major scientific festivals including the *Cheltenham Science Festival, Cambridge Festival of Ideas* (**Sommerlad**) and *Hay Festival of Literature*, as well as for specialist audiences (e.g., *BNA Christmas Symposium*: **Chait**) and by giving TED talks (**Haggard**, **Scott**, **Sharot**, **Walsh**) that have attracted over 4M viewers. We encourage staff to use social media to engage with the public, and both individual staff and Institutes within UoA4 are highly active on Twitter, Instagram and LinkedIn.

4.8 Indicators of influence and recognition

51% of staff have been awarded scholarly fellowships or related awards, with specific fellowships highlighted in §3.2. Many major honours/prizes have been awarded to staff at all career levels, including: CBE (**Scott**); Brain Prize (**Hardy**, **de Strooper**, **Dolan**); Fellowships of the Royal Society (**Behrens, N. Burgess**, **Kullmann**, **Maguire**, **Price**, **Rothman**) and British Academy (**Carston**, **Lavie**); Academy of Medical Sciences (**Brownstone**, **Dick**, **Greensmith**, **Hanna**, **Reilly**); Champalimaud Vision Award (**Bainbridge**); GG2 Outstanding Achievement in Medicine (**Cordeiro**); Philip Leverhulme Prize (**Raihani**, **Roiser**); Royal Society Rosalind Franklin Award (**Viding**); Pfizer Research Prize (**Bach**); British Psychological Society Spearman Medal (**Fleming**); Royal College of Physicians Baly Medal (**Kullmann**); European Psychiatric Association Pascale-Boyle Prize (**Killaspy**); Experimental Psychology Society Prize (**Norbury**); Multiple Sclerosis Research Prize (**Smith**); Society for the Neurobiology of Language Early Career Prize (**McGettigan**); British Psychological Society Public Engagement and Media Award (**Bell**); Leslie Gehry Benner Prize for Innovation in Science (**Tabrizi**); Weston Brain Institute International Outstanding Achievement Award (**Fox**); Consortium of MS Centres Lifetime Achievement Award, Dystel Prize, Sobek Foundation award (**Thompson**); Medical Research Foundation Emerging Leaders Prize (**Pingault**); Royal College of Physicians Graham Bull Prize (**Patani**).