Institution: University College London
Unit of Assessment: 4
a. Overview

This submission presents research in Psychology, Psychiatry, and Neuroscience conducted by 305 research staff within UCL's **Faculty of Brain Sciences** (FBS). The Faculty, created in 2011 to draw together research activity across these complementary areas, is one of four Faculties that comprise the UCL School of Life and Medical Sciences (SLMS). Staff returned here engage in basic, clinical, and translational research and lead clinical trial networks, and also collaborate extensively with other researchers cross-institutionally. Strong links exist with multiple NHS Trusts, consolidated by an NIHR Biomedical Research Centre (BRC) and Dementia Biomedical Research Unit, plus an Academic Health Sciences System (UCL Partners, UCLP). The vitality of this research is demonstrated by:

- Outstanding facilities and infrastructure, including major investment in staff, buildings, and equipment in the REF period;
- Over 13,000 peer-reviewed research articles published during the assessment period; 40% of submitted papers are in *Science*, *Nature*, *Cell*, and *Lancet* series journals, *Proc Natl Acad Sci (PNAS)*, *N Engl J Med (NEJM)*, *Brain*, and *J Neurosci*.
- External research income of over £260M, with income growth of nearly 30% over the census period; each staff member on average is awarded over £180K of external income per annum;
- Research activity sustained by vibrant doctoral training programs which award over 120 PhDs annually, with a 47% increase between 2008-9 and 2011-12;
- Major international influence: UCL ranks 2nd globally (behind Harvard) for research in neuroscience/behaviour and psychiatry/psychology, with research outputs being cited over a quarter of a million times in the past 10 years (Thomson ISI). UCL's share of the world's most highly cited papers in neuroscience is 23%, and the figure for neuroimaging is 27% (RAND). Three staff (Dolan, Friston, Thompson) are amongst the 20 most highly cited scientists globally in neuroscience and behaviour.
- Substantial engagement with industry, with >£15M of funding in the REF period, leading to major and diverse impacts as described in REF3a and our impact case studies.

The submission comprises six major units to which all staff are affiliated:
(1) **Institute of Neurology** (IoN; Director, Prof Mike Hanna), comprising the Research Departments of Brain Repair and Rehabilitation (Head, Prof Xavier Golay); Clinical and Experimental Epilepsy (Head, Prof Matthew Walker); Clinical Neuroscience (Head, Prof Tony Schapira FMedSci); Molecular Neuroscience (Head, Prof John Hardy FRS FMedSci); Neurodegenerative Disease (Head, Prof John Collinge CBE FRS FMedSci); Neuroinflammation (Head, Prof Kenneth Smith); the Sobell Department of Motor Neuroscience and Movement Disorders (Head, Prof Linda Greensmith); as well as 3 allied units: the Wellcome Trust Centre for Neuroimaging (WTCN; Head, Prof Ray Dolan FRS FMedSci); the MRC Centre for Neuromuscular Disease (Director, Hanna); and the MRC Prion Unit (Director, Collinge).
(2) **Division of Psychology and Language Sciences** (P&LS; Head, Prof David Shanks), comprising the Research Departments of Clinical, Educational and Health Psychology (Head, Prof Peter Fonagy OBE FBA); Cognitive, Perceptual and Brain Sciences (Head, Dr Joseph Devlin); Developmental Science (Head, Dr John Wattam-Bell); Language and Communication (Head, Prof Rosemary Varley); Linguistics (Head, Prof Ad Neeleman); and Speech, Hearing and Phonetic Sciences (Head, Prof Andrew Faulkner).
(3) **Division of Psychiatry** (DoP; Head, Prof Michael King), comprising the Research Departments of End of Life Research (Head, Prof Patrick Stone [from 2014]); Epidemiological Research (Head, Professor Glyn Lewis); Health Services and Clinical Research (Head, Professor Sonia Johnson); Mental Health of Older People (Head, Professor Gill Livingston); and Neuroscience of Mental Health (Head, Dr Elvira Bramon).
(4) **Gatsby Computational Neuroscience Unit** (Director, Prof Peter Dayan).
(5) **Institute of Cognitive Neuroscience** (ICN, Director, Prof Geraint Rees FMedSci).
(6) **Ear Institute** (EI, Head, Prof David McAlpine).
Research in UoA4 depends on strategic alignment with the NHS, exploiting co-location of UCL academics with the following partner NHS Trusts: University College London Hospitals Foundation

Trust (UCLH), including the National Hospital for Neurology and Neurosurgery; the Royal National Throat, Nose and Ear Hospital (RNTNEH); the Royal Free London Foundation Trust; Camden and Islington Foundation Trust; and the North East London Foundation Trust.

b. Research Strategy

The major research themes within UoA4 are ***neurodegeneration and neuroprotection***, 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; ***mental health,*** combining initiatives between basic neuroscience, clinical and epidemiological psychiatry and clinical psychology to address the global challenges of mental health problems; ***understanding and influencing human behaviour***, exploiting our 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 behavioural change interventions; and ***sensory systems and therapies***, bringing together expertise in audition, vision and cognition to transform understanding of the mechanisms underlying function and dysfunction in sensory systems, and developing and validating new therapeutic approaches in areas ranging from stem cells to neuroprosthetics. Key mechanisms for achieving our general strategic goals include:

- Major research centres: maintaining an effective research environment and infrastructure, based around strong research groups led by outstanding individuals and funded by regular and longer term research grants.
- Interdisciplinarity: supported by a cross-School Neuroscience Domain that facilitates and resources collaborative work incorporating a broad range of related disciplines and UCL's Grand Challenges programme (especially the Global Health and Human Wellbeing themes).
- Career development: operating a well-structured career development programme for both junior and senior academic as well as research staff, including mentoring and future leaders programmes and continual interaction within and across research groups.
- International interaction: interacting globally through visitors, numerous international collaborations (e.g. Max Planck Society, Yale, Zurich), hosting conferences and a high intensity of international conference participation, training networks, major involvement in editorial work for leading international journals, plus staff and student recruitment.
- Enterprise and knowledge transfer in relation to significant issues in health and wellbeing: incentivising and supporting this key aspect of the research of staff members and of the research centres to which they are attached via institutional structures and procedures.
- State-of-the-art doctoral programmes: running well-resourced training programmes with significant teaching components (including PhD-specific courses in theory, methods, core skills and career development), opportunities for international exchange, major involvement with research centres, and extensive interaction with experts.

Strategies outlined in RAE2008

Our strategy in 2008 centred around the **development of neuroscience at UCL as a cross-cutting domain**, combined with **promotion of translational research underpinned by outstanding basic science** leading to **better diagnosis and treatment of disease**. We have made substantial progress towards these aims, including significant investment in people and infrastructure, as well as a major reorganisation to make UoA4 co-extensive with a single Faculty (FBS; Dean, Prof Alan Thompson), including restructuring in which the previous Departments of Psychology, Phonetics and Linguistics, and Human Communication Sciences were merged into a single Division (P&LS). Since its creation, FBS has put in place effective mechanisms to facilitate a common research strategy and to foster inter-disciplinary research collaboration.

Research Strategy for the next 5 years

FBS has formulated an ambitious strategy that incorporates the Faculty's core values and develops the complementary expertise contained within its constituent parts to realise our shared vision. Our strategy encompasses the full translational pathway spanning discovery science through experimental medicine, to disease prevention and the delivery of new treatments and

therapies. 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. The understanding of behaviour is fundamental to delivering evidence-based practice by clinicians, 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 key partners, which include:

The **Sainsbury Wellcome Centre for Neural Circuits and Behaviour**, funded (>£100M) by the Gatsby Charitable Foundation and the Wellcome Trust (WT) and based at UCL, will open in 2014 and will be at the heart of efforts to further strengthen research in systems-level neuroscience. The Centre will be built around the Gatsby Unit (**Dayan**, **Latham**) which will relocate there. As well as recruiting outstanding new research groups, the Centre will nurture close links with research groups in FBS. Neuroscientists working in the new facility will 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.

The **Francis Crick Institute** (formerly the UK Centre for Medical Research and Innovation) will open in 2015 under the Directorship of Nobel laureate Prof Sir Paul Nurse. UCL was chosen as the founding academic partner for the Institute because of its research excellence in life and medical Sciences, and it is located close to the UCL campus near St. Pancras station with funding of £750M from MRC, Cancer Research UK, Wellcome Trust, Imperial, and King's, in addition to UCL. It will employ 1,250 scientists and have an operating budget of >£100M. Its mission as an interdisciplinary medical research institute is to understand why disease develops and to find new ways to prevent and treat major medical disorders. UoA4 contributes leadership (**Rees**, part of the Crick Executive) and staff will be involved in research programmes (e.g. **Fisher** with Tybulewicz).

The **Leonard Wolfson Experimental Neurology Centre** (LWENC). In 2011 the Wolfson Foundation awarded £20M to UCL to establish a new centre and training programme (with a £1.25M contribution from Eisai) to understand and treat neurodegenerative diseases. It includes biobanking resources and facilities for biomarker analysis and research. The grant is the largest single award ever made by the Foundation and one of the largest philanthropic donations in UCL's history. The Centre will be based in the National Hospital, the partner hospital of the IoN, reflecting the importance of bringing together clinical and scientific excellence in the search for effective treatments for these devastating diseases. It is led by 8 staff from the IoN, has recruited a Facility Director as well as **De Strooper** (one of Europe's leading cell biologists working on Alzheimer's disease), forged important international collaborations (**Zetterberg**, with Gothenburg), and is funding a major new PhD programme in neurodegeneration. The Centre will play a significant role in relation to the £25M investment in 2012 from Eisai to establish a therapeutic collaboration.

The **NIHR Biomedical Research Centre** and the **NIHR Biomedical Research Unit in Dementia** are partnerships between UCLH and UCL that support experimental medicine research by investing in staff posts, equipment, facilities and training. Their combined budget is >£100M over 5 years, and they aim to turn innovations in basic science into treatments and therapies that have direct effects on patients. The BRC's Neuroscience Programme (Programme lead, **Wood**) focusses on biomarkers and neuroimaging to maximise exploitation of NHS data.

UCL Partners, UCL's Academic Health Sciences System, is one of the world's largest academic health science partnerships, covering a population of 6M people in North East and North Central London and surrounding areas, aimed at accelerating the translation of scientific discoveries into clinical practice by coordinating the process of discovery, facilitating clinical trials, creating opportunities for implementing findings, and providing a programme of evaluation for these implementations. In addition a high level of coordination is achieved between research and education and training. Its Integrated Mental Health Programme (directed by **Fonagy**) has a budget of ~£2M pa. In the area of multiple sclerosis, a pathway will be developed between the world-leading neuroscience research at UCL/Queen Mary (QMUL) and the hospital trusts to facilitate the rapid translation of research into new clinical therapeutics and treatments, the improvement of patient outcomes, and the dissemination of best practice. A joint strategic initiative (including BRC funding) working across Neuroscience, Cardiovascular, and Mental Health programmes will support a major academic translational development in the area of

cerebrovascular disease. It will facilitate recruitment of world leaders in stroke basic science and clinical trials working in the fields of ischaemia, neuroprotection, neuroimaging and genetics and will allow translation of novel treatments which can then be rapidly applied to the well-established and successful clinical stroke pathways across UCLP. For example, the initiative will allow the early diagnosis of cognitive impairment and delayed onset of dementia by aggressive treatment of cardiovascular risk factors across large patient populations. UCLP's bid for a *Collaborations for Leadership in Applied Health Research and Care* (CLAHRC) award has been funded (£9M) by NIHR from 2014. The CLAHRC will be hosted by Barts Health NHS Trust, supplemented by >£30M from other contributing institutions, and will involve several staff including **Fonagy** (Mental Health Theme Lead), **Livingston** (Dementia), **Osborn**, **Pilling**, and **Johnson** (Adult Mental Health), **Michie** (Health Behaviour), and **M. King** (PRIMENT Clinical Trials Unit [CTU]).

The **Max Planck-UCL Centre for Computational Psychiatry and Ageing** (Director, **Dolan**) is a £6M joint investment due to open at the IoN in 2014. The scientific goal of the Centre is to develop and apply computational methods to improve our understanding of mental illness and behavioural ageing. A computational, personalised lifespan approach will be taken by identifying neural and behavioural parameters that predict more or less favourable age trajectories, with the intent to intervene in time when undesirable outcomes are expected.

IMANOVA. A collaboration between MRC, UCL, Imperial, and King's, IMANOVA has received £47M of investment in equipment and infrastructure since opening in 2007. It provides state-of-the-art facilities for imaging sciences, radiochemistry, and their application to drug and diagnostic development. Staff from the Faculty are now involved in several major research programmes including collaborations between **Roiser** (UCL) and Howes (KCL) on the role of 5-HT in major depression, and **Rees** (UCL) with Kapur (KCL), Nutt (Imperial), and Rabiner (IMANOVA) on imaging neurotransmitter release.

There are four key cross-cutting components to our strategy:

A. Neurodegeneration and neuroprotection

Staff undertake fundamental discovery neuroscience, preclinical evaluation across a range of neurological diseases using in vitro and in vivo models, and clinical trials in patients with neurological diseases. We apply integrative molecular, cellular, neuroimaging, epidemiological and cognitive approaches to neurodegenerative disorders affecting the brain, the auditory and visual systems in order to define disease, illuminate mechanisms of pathogenesis, and guide design of therapeutic interventions for disorders of the nervous system. Our integrated approach aligns with the neuroscience theme of the UCL/UCLH BRC and the Institute of Ophthalmology (IoO)/Moorfields BRC plus neurology research within the ICH/GOSH BRC. To be successful we will need to harness the skills of a wide range of scientific specialities including structural biology, medicinal chemistry, computational biology and engineering approaches to biology. The Francis Crick Institute and Sainsbury Wellcome Centre offer unrivalled potential for new interactions and therefore we will develop a proactive and interactive relationship with these Institutes. Partnership with industry will be key and we will also develop collaborative relationships with the outstanding basic neuroscience at UCL and form linkages with other UCL Faculties (e.g. for machine learning, IT and data handling).

Specific goals are to: (1) establish a world-leading facility for experimental medicine, the LWENC; (2) strengthen and complement existing molecular and cellular expertise in the neurobiology of neurodegenerative disease; (3) develop novel therapeutic strategies for neurodegenerative diseases through establishing a pipeline for identifying targets, and molecules affecting these targets; (4) establish new interfaculty and inter-institutional collaborations; and (5) 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.

Strategic achievements in the REF period

A1. Our research in **neurodegenerative disease** has at its core aim the understanding of the molecular bases of neurologic disorders. Research encompasses all the major neurodegenerative conditions including Alzheimer's disease (AD) and related disorders, Parkinson's (PD) and Huntington's disease, ALS, motor neurone disease (MND), and frontotemporal dementia, as well as studies of the pathways of cellular senescence. Multidisciplinary and interactive research spans structural and molecular biology, neurogenetics, cellular and transgenic mouse models, and the full

spectrum of clinical research including major cohort studies and therapeutic trials. Identifying causative and predisposing genes is a fundamental route to understanding and studying these diseases. Staff continue to make substantive contributions in this area by their recent identification of genes involved in dementias, movement disorders, and neuromuscular diseases. A key component is the new LWENC that will exploit basic science discoveries emerging from genetics and molecular neuroscience to deliver new treatments.

Major awards include: the MRC Centre of Excellence in Neurodegeneration (£1.2M), which includes a formal arrangement with German, Italian and Canadian Centres of Excellence; WT Joint Senior Investigator award (**Fisher** with Tybulewicz at MRC NIMR, £2.8M); significant awards in Huntington's disease research (**Tabrizi**, High Q Foundation £1.7M; EU £1.6M), including grants totalling £14.9M awarded by CHDI Foundation during the REF period to support the TRACK HD clinical studies led by **Tabrizi**; and ~£1M in research funding from Parkinson's UK. Significant funding has been awarded to support research in prion diseases (within the embedded **MRC Prion Unit**, Director **Collinge**, renewed for £31.5M) including: Health Protection Agency award to estimate prevalence of vCJD infection (**Brandner**, £1.6M); DH grant renewal for the development of small molecule therapeutics for prion disease in collaboration with GlaxoSmithKline (**Collinge**, £4.8M); MRC award to develop humanised monoclonal antibodies for prion therapeutics (**Collinge**, £5.1M); and DoH award to support the National Prion Monitoring Cohort (**Collinge**, £3M).

Significant new appointments in this area include **Isaacs**, recruited to lead basic and translational research into frontotemporal dementia, **Rohrer** to research biomarkers of frontotemporal dementia, and **Schott** to conduct translational dementia research. The appointment of **Ule** (with **Patani**, WT clinical fellowship, £900K) has greatly enhanced our expertise in RNA biology, a field of tremendous importance to a range of neurodegenerative diseases (*Cell*, *Nat Neurosci*), and that of **Morris** will augment research on the aetiology of PD and the genetic basis of young-onset disease in particular. **Houlden** (MRC Senior Fellowship, £1.5M) and **Wood** have led in the discovery of several new genes for dystonia, parkinsonism and related conditions. With the advent of next-generation genotyping and sequencing strategies, staff have also played a leading role in the identification of risk loci for disease including the discovery of new genes involved in AD and MND (*NEJM*, *Neuron*), and have led or participated in the recent successful genome-wide association studies of PD, PSP, AD and MND (all published in high profile journals such as *Nat Gen* and *Lancet*). These studies have yielded an increasing awareness of the importance of gene regulation in the pathogenesis of diseases of the nervous system. **Hardy's** success in obtaining MRC funding (£1M) for the construction of a human brain gene expression database is a major part of this effort. A significant emerging theme in genetic analyses of PD and MND has been the importance of mitochondrial homeostasis and this has also continued to be a rich research area with major papers on this theme from recent recruits **Plun-Favreau** and **Abramov** (*Neuron*, *Nat Neurosci*). The use of exosomes to deliver short-interacting RNAs for therapy of neurodegenerative diseases has been pioneered in conjunction with collaborators in Oxford and published in *Nature* and *Lancet* series papers. Other major contributions include the world's first blood test for vCJD (*Lancet*), a genetic resistance factor for prion disease (*NEJM*), characterisation of two distinct phases of prion propagation (*Nature*); blocking interaction between cellular prion protein and toxic Aβ oligomers by monoclonal antibodies (*Nat Comm*); discovery of a novel prion disease presenting with diarrhoea (*NEJM*); ground breaking cohort studies in HD (*Lancet Neurol*); and a key international biomarker study in AD (*NEJM*).

The **UK Parkinson's Disease Consortium** is a major strategic initiative funded jointly by an MRC and WT strategic award (£5.9M, led by **Wood**, **Hardy**, **Schapira**), and including staff from Sheffield and Dundee Universities, which aims to understand the molecular bases of PD and related movement disorders with the goal of taking mechanistic therapies into the clinic. Productive collaborations especially between **Wood** and **Abramov** with colleagues from Cambridge have led to the demonstration of single molecule toxicity of synuclein (*Cell*). Basic science has been successfully translated into new treatments in neuromuscular muscle wasting neurological diseases including repurposing drugs for muscle channelopathies that has led to new European Medicine Agency orphan designation (*JAMA*).

Translational molecular neuroscience research is also conducted in the embedded **MRC Centre for Neuromuscular Diseases** (Director, **Hanna**), a partnership established in 2008 (£3M, renewed 2013, £3.5M) between the IoN, the UCL Institute of Child Health, and the University of Newcastle. It has developed a multidisciplinary research programme to catalyse the translation of

preclinical science into experimental trials and new treatments for adults and children with muscle wasting neuromuscular diseases. The Centre has developed national clinical trials networks, established a human muscle cell biobank for preclinical science/therapy testing with over 2000 human cells lines, pioneered MRI of muscle as a sensitive disease monitoring tool, and has recruited large numbers of patients into natural history studies and experimental trials.

The **Dementia Research Centre** (Director, **Fox**), is a multi-disciplinary clinical research group comprising over 50 staff collectively focussed on translational programmes in dementia. These range from identification of disease-causing genetic mutations to participation in large-scale genomic initiatives, including the clinical phenotyping of TREM2, the most significant genetic risk factor for AD to be identified since ApoE (*NEJM*). The Centre is closely linked to the Specialist Cognitive Disorders Clinic (National Hospital), which has a national referral base and has facilitated the establishment of large, well-characterised cohorts with rare, young-onset and familial dementias. The Centre currently conducts the largest UK-based studies of familial AD and frontotemporal lobar degenerations, which will provide platforms for future large-scale therapeutic trials in these diseases; and participates in the international Dominantly Inherited Alzheimer's Disease Network (DIAN) and the Alzheimer's Disease Neuroimaging Initiative (ADNI). The Centre's research funding reflects this broad, patient-focussed remit with substantial support from MRC and ESRC programme grants (**Fox** £1.4M, **Crutch** £2.2M) and charities notably including ARUK (**Fox** and **Schott**, £2M) and WT (Senior Clinical Fellowship, **J. D. Warren**, £1.2M). The Centre holds two five-year NIHR Senior Investigator awards (**Fox**, **Rossor**), and a £1M award (**Fox**/**Schott**) for a young onset AD programme. In partnership with Newcastle University, UCL was awarded the Coordinating Centre grant for the NIHR Dementias and Neurodegenerative Diseases Network (**DeNDRoN**, PI **Rossor**, renewed in 2010 for a further 5 years, £4.9M) and coordinates the England-wide research network, comprising seven dedicated local networks. The portfolio covers dementia, and PD, Huntington's, and MND. The **NIHR Queen Square Dementia Biomedical Research Unit** was established in 2012 (PI **Rossor**, £4.5M) with a research programme that comprises four themes: molecular mechanisms (**Collinge**), signatures of disease (**Hardy**), biomarkers of change (**Fox**), and novel therapies (**Rossor**). The first major output from the BRU (2013) has been the development of a chip for rapid diagnosis of genetic dementias.

A2. The focus of research in **neuroinflammation** is multiple sclerosis (MS). The research programmes are cohesive, with some themes (e.g. tissue energy insufficiency) uniting a part of the research of virtually all the members. MRI plays an important role, with research at pre-clinical (**K. Smith**, **Wheeler-Kingshott**), clinical, and clinical trial levels (**Miller**, **Wheeler-Kingshott**), facilitated by collaborations with **Golay**. **K. Smith** (from King's) was appointed to lead research aimed at understanding the pathophysiology of MS to develop novel therapeutic approaches for neuroprotection: this is the most important goal in MS research, but no such therapies are known. Neuroimaging plays a key role, ranging from imaging individual mitochondria in the CNS in vivo by confocal microscopy (**K. Smith**) to imaging mitochondrial function in animals and patients using MRI/MRS (**K. Smith**, **Miller**, with **Golay**). Notably, **K. Smith's** pre-clinical research has revealed the unexpected value of sodium channel blockade in neuroprotection, and this novel approach has been directly translated into three clinical trials (**Miller**), including work (*Lancet Neurol*) which described the first substantive clinical trial for neuroprotection in MS. We have established a clear lead in this field, with substantial funding from NIHR (**Miller**, £2.7M), research councils (**K. Smith**, MRC £760K; **Wheeler-Kingshott**, EPSRC £650K), charities, and industry that supports each stage of the overall programme. In addition, the award of a new programme grant from the UK MS Society has been a major achievement (**Miller, Ciccarelli**, **Wheeler-Kingshott**, **Golay**, **Yousry**, **Thompson**, £1.35M). Indeed, trials led by **Miller** encompass international programmes of MRI biomarker research with a total income >£10M. In key work (*NEJM*) a novel drug (BG-12) was found to provide good therapeutic effects in MS patients, reducing the rate of relapses (attacks) and progression (worsening), and also reducing the number of new lesions. A type of stem cell (autologous mesenchymal) can safely be given to secondary progressive MS patients, and evidence has been obtained of structural, functional and physiological improvement suggestive of neuroprotection (*Lancet Neurol*).

A3. We undertake basic and clinical research in **motor neuroscience and movement disorders** on a number of neurological disorders that affect the motor system, ranging from PD, dystonia,

stroke and MND to peripheral nerve and neuromuscular disorders. It brings together scientists who use a powerful combination of modern non-invasive research technologies (including theoretical and computational approaches and a variety of cellular, animal and human models) to explore how the brain controls normal movement and how disease leads to disordered control and loss of movement. Current clinical research programmes involve TMS, EEG, MEG, fMRI and structural MRI (VBM, DTI) methods, while translational programmes include use of cell culture, molecular and cellular biology, and transgenic approaches. Researchers also have a strong interest in the cognitive aspects of motor control, including brain mechanisms of decision making and response selection. This is supported by sophisticated neurophysiological techniques for the monitoring of large neuronal populations in active brain networks, and we lead research and clinical treatment using deep brain stimulation and recording.

There have been several major recruits including **K. Harris**, whose research focuses on how neuronal networks control behaviour, **Kennerley** who strengthens research in movement neurophysiology, and **Kilner** whose research focuses on the role of the motor system in our ability to infer others' beliefs and intentions. The most recent recruit is **Schiavo**, a world leader in the field of axonal transport and signal integration. Major grants and personal awards include funding from the Monument Trust to the Functional Neurosurgery Unit (**Hariz,** £1.2M), and WT New Investigator awards to **Kennerley** (£2M) and **K. Harris** (£1.3M). In addition, career development of young investigators has been supported by fellowships from BBSRC (**Bestmann**, £750K, **Davare**, £750K), WT (**Bays**, £731K; **Gandhi**, £800K), NIHR (**Edwards**, £690K) and EU (**Bestmann**, ERC £1M). We also receive significant support from MRC (**Day**, £880K; **Ward**, £520K; **Rothwell**, £380K; **Koltzenburg**, £410K), WT (**Lemon**, £520K), EPSRC (**K. Harris**, £707K) and The Brain Research Trust (BRT; Graham Watts Fellowship: **Greensmith**, £685K). Several staff also play key roles in a number of EU grants (**Greensmith**, **Foltynie**, **Lemon**, **Rothwell**, >£1.5M). A new chair of experimental neurosurgery will be appointed following an award (£1.6M) by the BRT.

Significant advances include showing that human decision making influences brain regions controlling movement even before the decision is finished (*J Neurosci*); that prefrontal neurons compute optimal choices (*Nat Neurosci*); and that despite the extensive recurrent connectivity of cortical circuits, cortical neurons can exhibit firing patterns of extremely low correlation (*Science*). Staff are pioneers in the development of transcranial brain stimulation protocols to examine early stages of synaptic plasticity in the human brain, results of which may be used to improve outcomes of rehabilitation in patients after stroke (**Rothwell**).

A4. The focus of our basic science in **epilepsy** has been to understand the fundamental workings of neurons, channels/receptors, synapses and brain circuits that govern brain excitability, memory and learning. Major achievements have been advances in understanding the fundamental role of physiological oscillations in information processing (*Neuron*, *Nat Neurosci*); the mechanisms regulating neuronal communication and neuron-glia interactions (*Science*, *Nature*, *Nat Neurosci*) and evidence of periodic bands in neural representation (*Science*). This research has resulted in individual awards/fellowships including WT Senior Investigator (**Kullmann**) and Principal Research (**Rusakov**, £2.8M, **N. Burgess**, £1M) Fellowships.

Translational research has focussed on the development of animal models of epilepsy and the development of new therapies. This has been greatly facilitated by the establishment of a bespoke rodent telemetry unit in collaboration with Open Source Instruments which enables continuous monitoring and analysis of EEG in freely moving rodents. One breakthrough has been the development of a gene therapy that can cure focal epilepsy in rodents (*Science Trans Med*). This is being progressed towards human trials. Clinical research has largely been centred on the epidemiology of epilepsy, epilepsy genetics, neuroimaging, neurophysiology and epilepsy surgery. The group leads two FP7 consortia: **Sisodiya** (>€5M) on epilepsy pharmacogenetics and **Koepp** (€7M) on developing imaging probes for evaluating response to treatments. This work has already resulted in a method of predicting drug resistance in epilepsy patients (*Lancet Neurol*). Highlights of the genetics work have been the identification of gene mutations resulting in alternating hemiplegia of childhood (*Nat Gen*), contributions to large consortia determining predictors of hypersensitivity to carbamazepine (*NEJM*), and genetic determinants of brain structure (*Nat Gen*). We are committed to phenotype/genotype research and have opened a new £3.4M epilepsy research facility located at and supported by the Epilepsy Society. The interface between research and clinical work is best illustrated by expansion of the epilepsy surgery programme (*Lancet*), and

this has driven much of the clinical neurophysiological, neuropsychological and neuroimaging research, funded by a WT Programme grant (**Duncan**). Staff members have also been at the forefront of developing simultaneous EEG and fMRI to understand brain networks underlying interictal and ictal activity (**Lemieux**) and have been the first to report simultaneous intracranial EEG and fMRI in humans (*Neuroimage*). Recent recruitment of **Rothman** (2013 Nobel laureate) as part of the UCL-Yale collaboration initiated in 2008 will enable the establishment of an innovative model organism laboratory which will use genetic manipulation of fly models to accurately study synaptic function in relation to major neurological diseases including epilepsy and channelopathies.

A5. Research in **stroke** has been enhanced by an HEFCE/DoH Clinical 'New Blood' Senior Lectureship Award (**Werring**), establishing a research programme into brain microhaemorrhages, supported by BHF/Stroke Association (£940K). On large vessel diseases, two international multicentre randomised trials comparing carotid angioplasty and stenting with carotid endarterectomy (CAVATAS and ICSS) were funded and directed by **Brown**. Results from these clinical trials indicate that endarterectomy is preferable (*Lancet Neurol*). **Brown** and **Werring** are also co-leads for the Thames Stroke Research Network (TSRN) (DoH, £2.4M), co-ordinating stroke research across a population of over 30 million (currently the highest recruiting UK Stroke research network with over 2200 patients in 2011-12). A study sponsored by TSRN found that acute, subclinical ischaemic brain lesions are frequent but previously underestimated after intracerebral haemorrhage (*Brain*).

In the area of **brain repair and rehabilitation**, major advances were made in the use of olfactory ensheathing cells to promote nerve repair, supported by >£2.2M funding, including an ERC fellowship to **Choi**. In rehabilitation, **Playford** secured a major grant from the Neurodisability Research Trust (£750K) for optimizing therapy and characterizing brain function in minimally conscious patients.

For **neuroradiology**, many clinical advances reported in the previous areas have been made possible in part by strategic investments in MR imaging, through a senior appointment in MR Neurophysics (**Golay**), plus creation of a new Neuroimaging Analysis Centre, interacting with other major neuroimaging facilities elsewhere in the UoA (e.g. WTCN). Recent developments led to the discovery of the value of glucose as a natural contrast agent (*Nat Med*).

B. Mental health

For the first time, key UCL departments focusing on mental health have come together to be part of a single Faculty creating the critical mass necessary to make UCL and its partners a world-leading centre for mental health research. To exploit this collaboration more fully, we have prioritised the further integration of all mental health related research at UCL supported by new appointments including a facilitator to coordinate and strengthen collaborative research activity across FBS, as well as other UCL faculties and departments (e.g. Faculty of Population Health Sciences) and strategic partners outside UCL (e.g. IMANOVA, Cambridge, King's). Our specific ambition is to combine the extraordinary strengths of FBS to: (1) make major advances in our understanding of the biological basis and development of mental disorders, and apply this knowledge to the design and evaluation of new therapeutic approaches; (2) research how evidence-based care is implemented to improve outcomes from innovative therapies for patient and population benefit; and (3) create a single knowledge hub for mental disorder at UCL with the establishment of an Institute of Mental Health Sciences rooted in the Faculty's strengths in neuroscience and treatment research.

We have already begun to bridge academic clinical psychiatry and neuroscience by making new appointments (e.g. in clinical psychiatry) and setting up collaborative grants between the WTCN and staff in clinical psychology. We will build on the strategic award to the WTCN by appointing jointly funded developmental neuroscientists and computational psychiatrists to take a developmental neuroscience perspective on the emergence of severe psychiatric morbidity in adolescence. The new LWENC will provide spin-off collaborations for clinical and scientific innovation in the management of mental health problems associated with neurodegenerative diseases. Through UCLP and its closely knit group of 6 mental health Trusts, we have gained access to the largest clinical population available for research in most diagnostic groups with the support of the Central and East London LCRN which covers an identical geographical area.

Academic appointments have expanded our research programmes and link work in these fields with existing achievements in epidemiological and social psychiatry, clinical and health psychology, and health services research. The administrative integration of neuroscience, psychiatry and psychology will deliver a step change in the profile of UCL mental health research equivalent to that effected for UCL Neuroscience. Senior appointments will develop further coordination between biological research and treatment evaluation in mental health, and will expand links between FBS and the new UCL Institute of Clinical Trials and Methodology which will bring expertise in translational treatment/service evaluations into the neuroscience domain.

Strategic achievements in the REF period

B1. Collaborative research on the epidemiology, genetics, neuroimaging and neurophysiology of **mental illness** has been significantly enhanced. Epidemiological and applied research has greatly expanded with awards including 6 major multicentre randomised trials funded by the NIHR HTA programme, 6 NIHR programme grants, and an NIHR Senior Investigator Award (**M. King**). Examples are reduction of cardiovascular risk in schizophrenia (**Osborn** and **M. King**, NIHR £2M), treatment of depression in family carers of people with dementia (**Livingston**, NIHR HTA £1.5M) and NIHR and MRC funded collaborations introducing new pharmacological and psychological interventions for psychosis (**Johnson**, **Joyce**). In parallel, we have developed the analysis of large clinical databases (GPRD and THIN) in areas such as physical health and mental illness (**Osborn**, **M. King**), bereavement (**M. King**) and mortality and morbidity in dementia (**Sampson**). Outcomes include improved understanding of psychological treatments in depression when antidepressants are ineffective (*Lancet*), effectiveness of art therapy in schizophrenia (*BMJ*), and the first risk prediction algorithms for onset of major depression (*Arch Gen Psychiat*).

In psychiatric services research, major grants have been awarded for multicentre programmes to develop and evaluate alternatives to acute psychiatric admission (**Johnson**, NIHR £2M) and assessment of standards and development of alternatives to rehabilitative care for schizophrenia in the UK and across Europe (**Killaspy**, NIHR £1.9M, EU €1.5M). Outcomes include assessments of recovery in rehabilitative psychiatric care in the UK and Europe (*Brit J Psychiat*) and treatment of depression in carers of patients with AD (*BMJ*). Psychiatric research in dementia continues to expand with funded NIHR trials of cognitive stimulation therapy in dementia and three grants (£9.5M total) awarded under the recent ESRC/NIHR Dementia Initiative (**Livingston**, **Higgs**, **C. Cooper**). **Strydom** led a significant recent collaboration (London Down Syndrome Consortium: LonDownS, WT Strategic award £2.5M) with other FBS collaborators and QMUL, MRC NIMR, and Birkbeck, to study Down's syndrome and AD with methods ranging from animal models (**Fisher**) and genetics (**Hardy**) to human neuroimaging and clinical mental disorders. Building on the dementia informatics initiative is enabling the mining of local mental health trusts' electronic records databases, not only in dementia but also in schizophrenia, depression and mild cognitive impairment (**Livingston**, **Osborn**). Genetics research focuses on the molecular genetics of schizophrenia, dementia and alcoholism as well as links with research on functional imaging and cognitive neuroscience. Work has included the contribution of detailed and well-diagnosed clinical phenotypes to patients' genetic samples in the highly successful Alzheimer's GWAS collaboration (**Livingston**, **Bass**, **McQuillan**, **Gurling**) and work on large recurrent microdeletions associated with schizophrenia **(Bramon**). Key outputs have revealed common sequence variants conferring risk for schizophrenia (*Lancet*), genetic variants in bipolar disorder (*Nature*), and rare chromosomal deletions and duplications in schizophrenia (*Nature*).

Effective collaborative research across these four main domains has been significantly enhanced by 6 new senior appointments (**Bass**, **Bramon**, **C. Cooper**, **Lewis**, **Sampson**, **Strydom**), including 3 HEFCE-supported 'new blood' clinical senior lectureships. Five MRC and one NIHR clinical training fellowships have also been awarded.

The **Marie Curie Palliative Care Research Unit** (Head, **Jones**) is based in DoP and conducts multi-disciplinary research into end-of-life care with experts in palliative medicine, old age psychiatry, health psychology, nursing, systematic review methodology, health economics and statistics. The Unit was awarded a major programme grant (through CRUK and Marie Curie Cancer Care [MCCC], £1.1M) to research end of life care in dementia and a major grant to **Serfaty** (NIHR HTA £1.8M) for a multicentre trial of CBT near the end of life. MCCC has also funded a new Chair and lectureship (£3.2M) to expand its research portfolio.

PRIMENT Clinical Trials Unit (joint Director, **M. King**) is a partnership between DoP, UCL's Research Department of Primary Care and Population Health, and Department of Statistical Science. The Unit collaborates with internal and external researchers to develop and/or evaluate complex interventions in primary care, psychiatric, and community settings and has a particular focus on the evaluation of mental health and behavioural change interventions. It is a UK Clinical Research Collaboration (UKCRC) registered CTU. It receives NIHR funding and currently supports 35 multicentre trials.

B2. Capacity in **clinical and health psychology** has increased with the recruitment of **Fotopolou** (ERC £1.1M) to study bodily self-representation, and **Fugard** and **Petrides** to enhance existing strengths in translational research in child and adolescent mental health and educational psychology, as well as the forging of strong links with the Anna Freud Centre and with Yale Child Psychiatry as part of the Yale-UCL collaboration. Research in neuroscience and developmental psychopathology has been strongly fostered through the establishment of the Developmental Risk and Resilience Unit (DRRU; led by **Viding** and **McCrory**) supported by large project grants from ESRC, MRC, and BA (£4.3M), which employs psychological, neuroimaging and genetic methods to study antisocial behaviour and childhood maltreatment.

Substantial gains have been made in external funding. The Centre for Outcomes Research Evaluation (CORE) has received £4.3M from the DH and NICE together with £4.2M linked grant support for the development of 24 NICE mental health guidelines (**Pilling**, **Michie**, **Fonagy**). A WT Strategic Award (£5.2M with Cambridge) is funding a programme aimed at understanding brain changes associated with the emergence of psychopathology (**Dolan**, **Fonagy**, **Fearon**). Research on PTSD (**Brewin, J. King**, MRC £450K) explores the value of virtual reality in treatment, and a trial of a new pharmacological treatment for cannabis addiction is being undertaken (**Curran**, **Kamboj**, MRC £1.3M). The Department for Children, Schools and Families funded the largest ever trial of treatment for conduct disorder, START (**Fonagy**, **Butler**, **Pilling**, £1M), and a follow-up has recently been funded (£1M) by the NIHR HSDR programme.

Key findings include the development of a novel technique based on an in vitro fertilisation sample of mothers to disentangle inherited and prenatal effects on human health and behaviour including smoking and antisocial behaviour (*PNAS*). **Viding** and **McCrory** have shown that callous traits are associated with reduced neural responses to others' pain in children with conduct problems (*Curr Biol*). Research has also explained the latent neural vulnerability to psychopathology in maltreated children who show neural adaptation in the anterior insula and amygdala to threat, a pattern which may confer short term survival advantages at the expense of longer term mental health (*Biol Psychiat*). Much work has been conducted on the development of MBT, an evidence-based treatment for BPD based on research on attachment and social cognition now in use across the world (*Am J Psychiat*). A substantial programme to develop a theory of PTSD (*Psych Rev*) has fed into revision of diagnostic criteria by both Amer Psychiatric Assoc and WHO (*J Abnormal Psych*).

B3. UCL is a world-leading centre for research on the use of **neuroimaging** as a tool for understanding mental illness. In particular the **Wellcome Trust Centre for Neuroimaging** brings together clinicians and scientists who study higher cognitive function using state of the art neuroimaging techniques, with the goal to understand how thought and behaviour arise from brain activity, and how such processes break down in neurological and psychiatric disease. The Centre achieved renewal of its core funding (2011 WT Strategic Award, £7.5M) and has made significant recruitments including **Montague** (WT PRF, £2M) to boost capacity in the neuroscience of social cognition and decision making, and the evaluation of biomarkers of mental disorders including drug addiction and schizophrenia (with **Fonagy**). **Barnes** has been recruited to lead the magnetoencephalography facility. New major awards have been made to **Price** (WT PRF, £1.7M), **Maguire** (SRF, £1M & PRF, £1.5M), **Dolan** (Senior WT Investigator Award, £1.3M), **Friston** (WT PRF, £2.4M), and **Weiskopf** (EU Brain Train Grant, £460K). As part of the Centre renewal there has been major infrastructure investment and refurbishment with replacement of two older scanners with two state of the art Siemens 3T scanners.

Research in the assessment period has highlighted impaired reward learning with advancing age that reflects a consequence of subclinical dopaminergic loss, remediable using l-dopa (*Nat Neurosci*) and the first work showing in humans a dissociation in the striatum between goal

directed and habitual value, an architecture that can explain deficits seen in PD, Huntington's Disease and following lesions to orbital prefrontal cortex (*Nat Neurosci*). Mathematical modelling of EEG recordings permitted a neural signature of consciousness to be identified in both healthy individuals and in brain damaged patients who retain some awareness (*Science*).

C. Understanding and influencing human behaviour

Our specific goals are to: (1) establish state-of-the-art research facilities for the study of cognition and behaviour, including investment in upgrading laboratories; (2) explore the cognitive and neural bases of behaviour in relation to wellbeing and apply this understanding to improve behaviour change interventions; and (3) strengthen and complement existing lifespan expertise in behaviour change.

The Faculty offers the opportunity to bring together and enhance our existing research to cover the entire lifespan: from infancy and childhood (cognitive and language development, developmental genetics of behaviour, attachment, education and school attainment, and health-related behaviours), through adulthood (health-related behaviours) to old age (cognitive aging, health-related behaviours), and includes both normal and abnormal populations. The emphasis on a lifelong perspective to understanding and influencing behaviour as a strategic priority highlights commonalities across research of the different parts of FBS and provides links to all the other strategic priorities, as well as significant opportunities for linkage with the Faculty of Population Health Sciences (Health Behaviour Research Centre) and the BRC. A pan-institution Centre for Behaviour Change is being launched in 2013 under the directorship of **Michie** with engagement from a range of disciplines beyond psychology including population health, the built environment, environmental sustainability and public policy.

We recognise and emphasise the critical importance of interactions within the physical as well as socio-cultural environment in shaping human behaviour across the lifespan and we will promote a research agenda that favours investigation of these interactions, linking to research in computer science and engineering (human-computer interaction, use of virtual reality to bring the physical and social world into the laboratory). We will make senior appointments in cognitive aging to strengthen links to research in neurodegeneration and the new LWENC.

Strategic achievements in the REF period

C1. **Cognitive neuroscience** has continued to mature as an area of considerable strength at UCL. Targeted recruitment has added **Diedrichsen** (computational motor control) and **Hamilton** (autism and social neuroscience). Together with the existing group leaders, housed almost entirely within a single building (Alexandra House) with purpose-built TMS and EEG facilities and local access to neuroimaging facilities, the local environment provides both critical mass and close proximity of intellectually complementary research groups. Alexandra House has benefited from ongoing refurbishment and enhancement of its public areas throughout the assessment period. Group leaders have secured a high proportion of personal fellowships, including WT SRFs (**Scott**, **MacSweeney**, each £1.1M), WT Senior Clinical Fellowship (**Rees**, £1M and £1.4M), WT Senior Investigator Award (**Roiser**, £1M), Royal Society URF (**Blakemore**, £330K), ESRC Research Professorship (**Haggard**), and a Royal Society Industrial Professorship (**Walsh**, £200K). **Hamilton** and **Bahrami** have been awarded Starter (£2M) and **Haggard** an Advanced (£1.2M) ERC grant.

We have established local strength in depth through major personal awards to intermediate research fellows including **Gilbert** (Royal Society URF), **Crinion** (MRC Clinician Scientist award), **Capelletti** (Royal Society Dorothy Hodgkin) and **Mercure** (ESRC Future Leaders Award). We have co-founded the Centre for Educational Neuroscience, a partnership with Birkbeck and the Institute of Education, which aims to develop this emerging discipline and to further translations of research into practice to improve education and well-being across the lifespan. Scientific highlights include the first demonstration of a neural basis for individual differences in human metacognition (*Science*), evidence that cooperating human dyads can outperform their individual members on demanding perceptual tasks (*Science*), evidence for grid cells in a human memory network (*Nature*) and demonstration of a failure to spontaneously mentalise in adults with Asperger's syndrome (*Science*).

C2. Research in **computational neuroscience** centres on the **Gatsby Unit**, a preeminent grouping of theoretical neuroscientists and machine learners, funded by the Gatsby Charitable

Foundation (£8M; renewed from 2011-2016). The Unit has been central to the development and creation of the forthcoming Sainsbury Wellcome Centre, which has largely been designed around an intimate relationship between theory, models and experiments, as suggested in RAE 2008. The Unit has also helped foster the cross-faculty Centre for Computational Statistics and Machine Learning, which is playing a key role in bringing methods for analysing and processing 'Big Data' to UCL, with relevance to neuroscience, psychology and beyond. The Unit enjoys numerous collaborations with the EI, the IoO, the Wolfson Institute for Biomedical Research, and the WTCN. Work on large-scale population coding (**Sahani**) was funded by a major award (£1M) from DARPA in association with Stanford (*Neuron*). Studies of the dynamical properties of cortical networks (**Latham**) showed severe limits to the utility of precisely timed spikes (*Nature*). Investigations of normative decision-making (**Dayan**, **Latham**, **Sahani**) led to initiatives in the nascent field of computational psychiatry, looking at the nature (*PNAS*) and underpinnings (*Neuron*) of biases. **Hassabis** was awarded a Henry Wellcome fellowship (£250K) to study future thinking.

C3. Research in **cognitive science** has undergone a period of significant development, including staffing expansion of around 25% since 2008 with coalescence around several major research themes: cognitive and decision sciences, behavioural neuroscience, multimodal communication, deafness and sign language, and social cognition. This has been accompanied by recruitment in each of these areas to give each a critical mass. **Love** was recruited from the University of Texas to spearhead the cognitive and decision sciences programme, together with early career researchers in the same area, **A. Harris**, **Speekenbrink** (a mathematical psychologist), and **Sharot** (WT Career Development fellowship, £740K). This group has received substantial external funding, including ESRC awards (**Harvey**, £380K; **Lagnado**, £340K; **Shanks** £560K), and produced high impact research in forecasting and causal reasoning, optimism bias, Bayesian encoding and implicit processing (*Science*, *Nat Neurosci*, *PNAS*). The social cognition group was founded with the recruitment of two researchers in 2008 (**Guinote**, **Richardson**) followed by two more in 2012/13 (**Custers**, **Krumhuber**), creating a vibrant social psychology section with a strong profile in areas such as unconscious processing, power dynamics and social gaze (*Science*, *Psych Sci*).

The development of animal models of cognition has been a major focus of the behavioural neuroscience group. In order to develop cross-UCL links on neural dynamics of cortical microcircuits and neural coding and decoding, two in vivo electrophysiologists (**Solomon**, **Bendor**) have been recruited who study single neuron processing in visual and auditory cortex respectively, and who will complement the group's existing strengths in spatial cognition (**Cacucci** for development and **Jeffery** and **Spiers** for space, memory, and sensory integration). Significant findings from this group include work on development of the neural representation of space, three-dimensional spatial encoding and hippocampal replay (*Science*, *Nat Neurosci*, *Behav Brain Sci*). In addition to funding from BBSRC (£345K) and MRC (£350K) to **Jeffery**, the group has gained an ERC starter grant to **Cacucci** (£1.2M) and a McDonnell scholarship to **Spiers** (£600K). The newly-established mulitimodal communication group has benefitted from extensive laboratory refurbishment and new facilities for multimodal research, together with the recruitment of a new researcher (**Skipper**, neural basis for language and action) and the award of an ESRC Future Leaders fellowship to **Vinson**. **Rodd** (£300K) and **Vigliocco** (£600K) have received substantial support from ESRC. Research highlights include work on integration of linguistic and modality-related information (*Curr Biol*, *Psych Rev*).

C4. Research in **language and communication** has been strengthened around core research themes of cognitive neuroscience of language, conversation and communication disorders, and speech and swallowing, with cross-cutting strands in clinical assessment and intervention, and clinical technologies. A senior appointment (**Varley**, from Sheffield) has promoted integration of research across neuroscience and speech and language therapy, and **J. E. Warren** was recruited to strengthen the neuroscience theme. The Conversation and Communication Disorders group has attracted significant funding over the survey period, including an ESRC grant to **Beeke** and an NIHR Postdoctoral Fellowship to **Bloch** (£320K). The Speech and Swallowing group increased its profile with a Dunhill Medical Trust award to **C. Smith** (joint with Birmingham), and strong engagement with industry through funded collaborations (Fresenius Medical Care). In addition to outputs in clinical journals, work from the group has been published in *Brain*, *J Exp Psychol*, and

Neuropsychologia. A strong strand of translational research has been developed, with British Academy (**Bloch**) and ESRC Follow on Funding (**Beeke**) to develop e-learning resources for clinicians and people with aphasia, together with clinical software development to facilitate high intensity interventions for post-stroke speech and language impairments.

The **ESRC Deafness, Cognition, and Language Research Centre** (DCAL, Co-Directors, **Woll**, **Vigliocco**, **MacSweeney**, with Morgan from City), was established in 2006 with an ESRC Centre grant of £3.7M, renewed in 2010 for a further 5 years (£4.4M). DCAL has successfully established itself as the premier centre for research on deafness and sign language in Europe with a unique record for capacity building of researchers who are deaf themselves. Its research focuses on how communication is shaped by deafness and the use of sign language, and how deafness and early language experience impact on cognitive functions. DCAL has secured £10M in additional grant income, including ESRC funding (£1.2M) to develop a corpus documenting sign language variability across the UK and (£730K) to investigate how linguistic stimuli interface with sensory, motor and affective systems. **MacSweeney** was awarded a Wellcome SRF to investigate reading in deaf individuals. New staff include **Vinson** and **Mercure** (as noted previously) who both obtained ESRC Future Leaders Fellowships to study multimodal integration and the neurobiology of sign language, respectively. Key findings include the discovery of separate contributions of auditory deprivation and language experience to brain plasticity in individuals born deaf (*Nat Comm*), and the importance of iconicity in early language acquisition (*Psych Sci*). In addition to academic achievements, DCAL led on the establishment of the first NHS clinic for deaf adults with acquired neurological impairments (especially those relating to aging) at the National Hospital.

Research on language development has been enhanced by creation of a dedicated laboratory with cutting-edge facilities (including EEG and eye and whole body motion tracking) for developmental behavioural and cognitive neuroscience research. Importantly, it provides a focus for collaborative projects across UCL (including the Institute of Child Health, the IoO, and Great Ormond St Hospital, in addition to other Faculty groups). Recruitment of new staff has enhanced basic and translational research. **Hulme** is a key senior appointment who has already secured £1.2M funding from the Education Endowment Foundation and is delivering high-impact research into the origins and remediation of literacy problems in children (*PNAS*, *Psych Sci*) with significant impact on educational policy and practice. Two junior appointments (**Halliday** and **Perovic**, the former supported by an ESRC first grants award), have extended research on language development into important new directions including the role of auditory processing deficits in the development of language disorders such as specific language impairment and dyslexia. An ESRC award (£600K) to **Best** is supporting collaboration with Birkbeck and the Institute of Education on the development of a pioneering multidisciplinary approach to lexical retrieval difficulties in children.

Research in linguistics provides the theoretical underpinnings for much of our applied language research and spans all major areas (syntax, phonology, semantics/pragmatics). These areas are explored in purely theoretical terms, as well as from a psycho-linguistic perspective (language acquisition and language processing). There has been a period of rapid development and expansion, with three new appointments in strategic areas. **Nevins** was recruited from Harvard to create a viable phonology group; **Santi** from McGill to strengthen research in psycho/neuro-linguistics; and **Sudo** from CNRS (Paris) to create a new group in formal semantics. There is an institutional commitment to two further appointments (in phonology and psycho-linguistics). The growing influence of research in this area has been recognized in the field. Staff are currently editors of three leading journals (*Linguistic Inquiry*, *Natural Language and Linguistic Theory*, and *Syntax*), and research over the REF period has been supported by 4 AHRC grants, two BA grants, an ESF grant and two Leverhulme grants. A rich stream of research explains word order phenomena without appeal to prefabricated structural positions (*Ling Inquiry*, *Syntax*), and work by **Nevins** comprehensively refutes Everett's claim that the Amazonian language Pirahã lacks recursion and other properties thought to be integral to the language faculty (*Language*). One strategic aim in recent years has been to develop new strands of experimental research that are firmly grounded in theory. The majority of staff are now involved in experimental work, using techniques such as cross-modal priming and eye tracking, as well as web-based data gathering. In addition, cross-disciplinary alliances have been forged with language researchers elsewhere in UCL and other institutions internationally (e.g. the ESF-funded XPrag network). This strategic aim has been internally supported by new equipment including two eye trackers.

D. Sensory systems and therapies

This major FBS theme includes research in the Institute of Ophthalmology, submitted to UoA1. Research in this area will be enhanced through links with the other Faculty strategic themes (especially in neurodegeneration and neuroprotection), the UCL Institute for Biomedical Engineering, the Francis Crick Institute, and the Sainsbury Wellcome Centre. Our specific goals are to: (1) build an integrated programme of translational research taking a regenerative medicine approach to hearing loss and visual impairment; (2) create a new focus of investigation targeting novel approaches and technology to interface with sensory systems. The emphasis will be on modifying both the biology of the transducing cells in the periphery as well as refining and developing technologies to interact with the sensory brain; (3) develop and validate new technologies for assessing hearing and vision that will refine studies of pathogenesis and the life course as well as deliver the next generation of experimental medicine tools for application in 'smart trials'; and (4) further our understanding of the degeneration and degradation of sensory systems with aging to identify novel strategies to optimise quality of life in the aging population. This work will parallel cross-faculty initiatives in neurodegenerative disease that will also inform how we optimise information flow in compromised sensory systems.

Strategic achievements in the REF period

D1. Basic and clinical **auditory research** has continued to develop and expand. A small-animal imaging laboratory in magneto-encephalography (MEG) has been established, one of only a handful of such laboratories worldwide, to provide a means of bridging small-animal and human investigations of auditory processing. Several significant research collaborations with commercial partners have been developed, including a successful €4M EU grant (**McAlpine**), with the cochlear implant company Neurelec, the University of Oldenburg, Germany, and the hearing-technology company Hoertech, as well as a major EU programme for the management of balance disorders (**Bamiou**, €4.3M). Other recent major awards include MRC Programme Grants (**McAlpine**, £1.4M; **Birchall**, £2.8M), a WT Sir Henry Dale Fellowship (**Bizley**, £1.2M) and an NIHR Professorship (£1.6M) that underpinned the recruitment of **Schilder** (paediatric otolaryngology). **Schilder's** establishment of the UK's first programme explicitly supporting clinical trials in ENT medicine ('evidENT') addresses a national priority in the field. The EI's increasing profile in this arena has been realised with a phase-1 clinical trial for a pharmaceutical therapy for hearing (with GSK spin-out Autifony). **Birchall** is a senior recruitment, responsible for the world's first stem-cell laryngeal transplant, establishing the EI as a world-leading centre for regenerative medicine (*Lancet*). Publication highlights in basic neuroscience include work on the transduction channels in hearing organs of Drosophila (*Nat Neurosci*), revealing how brain mechanisms enable 'cocktail-party' sound localisation in human listeners (*PNAS*), and a randomized clinical trial of the efficacy of antibiotic treatment for middle-ear disease (*BMJ*).

Work focussing on the perception and production of speech has generated high-impact outputs including **Faulkner**, **Rosen**, and **Scott's** demonstration that activity in the inferior frontal gyrus is a marker of the ability to adapt to distortions of speech typical of cochlear implants (*J Neurosci*), and research by **Iverson** with **Leff** showing that the locus of neuronal responses to perceptually equivalent acoustic differences varies between speech and non-speech contexts (*PNAS*). A European collaborative base includes a role as partner in the Marie Curie training network INSPIRE (£400K). Beyond Europe there are funded collaborations involving **Evans** (with Best, Western Sydney, ARC-funded), **Xu** (with Whalen, Haskins labs, NSF-funded) and **Rosen** (with Sousa, Northwestern, MRC-funded). **Huckvale** received a WT Translational Award (£1.3M) supporting a clinical trial of Avatar Therapy for voice hallucinations in schizophrenia. His innovative real-time voice morphing technology is fundamental to this work, which follows from a successful NIHR-funded pilot (*Br J Psychiat*). Internal investment in a 64-channel EEG/ABR acquisition system has stimulated substantial new activity. This includes two related ESRC grants (£800K) to Iverson which use EEG to study the learning of 1st language speech sounds in infants and 2nd language sounds in adults. The recruitment of **Adank** has broadened activity in the neuroscience of speech processing to include speech production. WT infrastructural seed funding for this appointment established a new TCDS and EMG speech lab in Chandler House, where one major focus will be the role of imitation in learning 2nd language speech sounds (*Psych Sci*). A 2013 Leverhulme Trust award to Adank assures effective use of these new facilities.

D2. In **vision**, two new staff holding personal funding were recruited, **Schwarzkopf** (ERC Starter grant, £1M) and **J. Greenwood** (MRC Career Development grant, £600K). Key findings from this group include the microstructure of cortical maps, and cortical mechanisms of visual crowding (*Nat Neurosci*, *Curr Biol*). Relocation of the Visual Development Unit (**Wattam-Bell**) to Chandler House has made a major contribution to the available facilities. Key findings from the VDU include important new insight into the developmental reorganisation of visual cortical pathways (*Curr Biol*) which is informing research into developmental disorders, including RCTs of early interventions in very premature infants.

Relation to other UoAs
A further unit within FBS is the IoO, whose research (as noted) is returned in UCL's submission to UoA1. There are close and extensive research collaborations between these sections, most notably within the sensory systems research theme and with other Faculties in SLMS (UoAs1, 2, and 5, especially clinical trials and basic neuroscience) and with the Faculty of Engineering (UoA11, especially human-computer interaction and machine learning).

c. People, including: i. Staffing strategy and staff development

FBS is committed to **sustaining an active research culture as its highest priority**. Attention to developing research excellence marks our policies at all levels, including annual staff appraisal and objective-setting interviews in UCL-wide formal procedures. In 2013, UCL received the European Commission HR Excellence in Research Award, acknowledging our robust and public implementation strategy for improving the career development and management of researchers. The award focuses on the implementation of the principles of the RCUK Concordat to Support the Career Development of Researchers.

The development of an international research profile is the expected norm and is a key feature of mentoring and staff review during lecturers' probationary periods. This policy is also implemented through research excellence as the major criterion for staff appointments 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.

Recruitment, mentoring, and career development
FBS has committed considerable resources since 2008 to staff recruitment to ensure succession planning and the sustainability of research groups. These include new readership/professorial appointments and junior posts, as described in our Research Strategy in section b above. **Staffing has increased by >40% FTE on a like-for-like basis since RAE2008**.

Early career academic staff show exceptional research promise. Staff recruited as lecturers since Jan 2012, for instance, joined on average 6 years after completing their PhDs with an average of 11 peer-reviewed journal publications. All are returned as research active, and since joining, most have secured significant grant support. Generous start-up funds are provided to enable new lecturers, including early career staff, to set up their research, and care is taken to limit teaching and tutorial loads during the 3 years of probation. A formal workload monitoring system across all academic staff is an important tool for allocation of teaching and administrative duties. In addition to recruitments of outstanding researchers to enhance the research environment, we also aim to promote job security for high achieving research staff. Since 2008, a significant number of individuals have moved from time-limited research contracts to tenured academic posts either at UCL (e.g. **Otten**, **Crinion**) or around the UK and the globe (e.g. Berry, Plymouth; Moran, Virginia Tech; Fontaine, Indiana; Frank, Nijmegen; Pillow, UT Austin; Pattamadilok, ULB Brussels; Schembri, La Trobe, Australia; Zultan, Ben-Gurion, Israel).

FBS encourages staff to apply for prestigious and competitive personal research fellowships in open competition in order to enhance their development and the vitality of their research groups. Since 2008, 134 fellowships have been awarded (further details in section d).

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. The SLMS Academic Careers Office plays a key role in promoting, supporting, and developing clinical

academic careers via co-ordination of the MBPhD and NIHR Academic Clinical Fellowship and Clinical Lecturer schemes, which are among the largest in England, with 91% retention rate in clinical academic training. The annual UCL Neuroscience conference brings together nearly 1000 clinical and basic researchers.

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. Academic and research staff are recognised and rewarded via the Faculty's robust set of processes for promotion, with clear criteria that are addressed through the annual appraisal system. Promotion decisions are exclusively informed by the individual's ability and achievements rather than the availability of grant funds. Since 2008 **26 staff have been promoted to professorships, 44 to readerships or principal research associate status, and 19 to senior lecturer**.

We have successful **mentoring systems** both for academic and research staff. Prospective mentors are provided with training through the online mentoring platform (uMentor) developed by UCL Human Resources. Mentors are more experienced staff working in a similar area as the mentee but without direct management involvement. We also participate in the SLMS 'Future Fifty' mentors scheme and 'Future Leaders' training scheme for future academic and clinical leaders at UCL. Following a successful pilot, UCL is participating in the establishment of the 'B-MEntor' cross-institutional mentoring scheme for academic and research staff from Black and Minority Ethnic (BME) backgrounds (in partnership with other London institutions). The mentoring lasts for an academic year and a comprehensive training and support package is provided to mentors and mentees. The SLMS **Early Career Neuroscience Forum** (ECNF) enables early career researchers (both post-doctoral and junior PIs) to meet their peers, to share experience and initiate collaborations. It also provides careers advice (e.g. clinical academic careers workshops) and disseminates 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.

Staff take full advantage of 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. We have a commitment to **continuing professional development** for academic and research staff at all levels. UCL provides a large variety of **short courses** ranging from presentation skills for junior personnel to leadership development for senior staff. Staff have access to UCLP multi-professional and on-site taught modules and the UCL Professional Development Programme for Researchers. Staff are encouraged to use the Researcher Development Framework professional development tool to enhance the knowledge, attributes and skills required for success as professional researchers. Funds are available through the UCL Graduate School for conferences, and exchanges with other academic institutions are actively encouraged. Since 2008, 15 staff have worked for time periods between two weeks and three months at institutions such as UCSD, the Scripps Research Institute, and Cold Spring Harbor Laboratory. Research staff on short-term contracts are given preferential access to continued employment through the UCL redeployment scheme. This requires senior staff making new appointments to consult the register for individuals whose contracts are coming to an end, and ensures that they are considered before any post is advertised externally.

Equality

Equal opportunities are supported from the highest level in UCL, with UCL Council having members specifically assigned to gender, disability, age, race, religion and belief, and lesbian, gay, bisexual and transsexual equality. UCL policy is that those interviewing job applicants must have been trained in equal opportunities issues and at least 25% of interview panels should be women. Each Dean is also specifically appraised annually on their Faculty's progress towards equality and diversity goals.

We are committed to monitoring and delivering improvements in the equalities profile at all levels. The introduction of a more inclusive and considered promotions process, the award of contributions points, representation on committees, and annual professorial pay evaluations support this process. Succession planning and developing improved careers management and peer/buddy schemes are intended to further support this work. UCL has established a new Dignity

at Work policy and advisory system designed to support staff in relation to gender equality, sexual orientation, and bullying. In 2013 UCL became a Stonewall Top 100 Employer for LGBT staff. We are also committed to the **promotion of women in STEM subjects**. Of the FBS units, P&LS/ICN has been an Athena-SWAN Silver recipient since 2009 (renewed 2013), and DoP and IoN attained Silver and Bronze status, respectively, in 2013. UCL renewed its institutional Athena SWAN Bronze award in 2013. Both **Maguire** and **Blakemore** have been awarded the Royal Society Rosalind Franklin Medal, to promote women in STEM, during the assessment period.

To assure work-life balance all key organisational meetings occur in core working hours, the opportunity for flexible working is promoted, and funding is provided to ensure reasonable adjustments are made in the workplaces of staff with disabilities (e.g. modification of office lighting and furniture, acquisition of software, loop provision in all lecture/seminar rooms, securing of funding from the Access to Work programme) and with family responsibilities (carers, paternity, and maternity leave). Objectives are being agreed to deliver improved ethnic balance at the higher levels in the longer term, with training and panel reviews to ensure that bias and discrimination are eliminated over time. The Faculty compares favourably across UCL and nationally with regard to gender balance and reward, but further work is needed and this is reflected in written action plans. In this UoA there were no significant gender or ethnicity differences in the proportions of selected versus eligible staff.

c. II. Research students

Postgraduate training is a key component of our research and scholarly activity. Intake in 2012-3 was 154 students (**up by over 61% in the REF period**), and **~500 doctoral students** in total conduct research, including those on professional training programmes. **670 doctorates have been awarded in the period 2008-2013, with external PhD funding totalling £12M**. Our commitment to doctoral research training is evident in initiatives on recruitment, programme development and the research culture.

UCL operates a number of structured 3- and (mostly) 4-year PhD programmes with supervisors in this UoA:

- We have been successful in obtaining consistent funding (>150 awards in the REF period) through UCL's MRC, BBSRC, ESRC and EPSRC Doctoral Training Centres, and AHRC. The ESRC DTC includes pathways in Psychology and Linguistics. MRC funding supports separate programmes in Biomedical and Life Sciences, Mental Health, and Clinical Neurosciences (jointly funded by the BRT). The London Interdisciplinary Biosciences PhD Consortium is a cross-institutional BBSRC-funded DTC (£5.4M).
- The WT/MRC 4-year PhD Programme in Neuroscience (6 per annum).
- The MRC Centre for Neuromuscular Diseases offers a 4-year translational PhD programme and has awarded 10 non-clinical and 7 clinical studentships in the REF period.
- The Centre for Mathematics and Physics in the Life Sciences and Experimental Biology (CoMPLEX) 4-year PhD programme (14 pa), funded by MRC, EPSRC, BBSRC, and the British Heart Foundation.
- The LWENC has launched a PhD programme (6 pa) in neurodegeneration which is funded jointly with £2.5M support from Eisai.
- UCL has introduced two PhD studentship programmes to enhance capacity. Impact studentships involve collaborations with industry or third sector organisations, with UCL providing 50% of the funding from internal resources. The SLMS Grand Challenge studentships are co-funded by UCL and the BRC. 78 studentships have been funded through these schemes, involving collaborations with funders from the pharmaceutical (AstraZeneca, GSK, Eisai, Merck), manufacturing (Philips, Research in Motion, Toyota), retail (Dunnhumby), and other sectors. 4 CASE studentships have also been awarded.
- The UoA has established a UCL-National Institute of Mental Health (NIMH) Joint Doctoral Training Program in Neuroscience (2 pa).
- The Gatsby Unit PhD Programme in theoretical neuroscience and machine learning.

The 4 year programmes provide students with numerous benefits, including rotation placements in different labs to learn about a range of topics and techniques. Some programmes require that a student be supervised by 2 academics with different areas of expertise.

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 DClinPsy programme (~50 students pa) combines professional clinical training with comprehensive research training in the largest programme in Europe. The Doctorate in Educational and Child Psychology (15 pa) 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 (15 pa) provides doctoral level research training for experienced educational psychologists holding masters-level qualifications. This programme, which has ESRC recognition, plays an important role in developing the research skills of professionals increasingly required to engage in evidence-based practice, and the great majority of these part-time students are sponsored by their employer. Much of the research training is common across the two doctorates, including an innovative WebCT course on research methods. The Doctorate in Clinical Communication Science (~2 pa) is a 4-year part-time programme designed for professionals working in clinical settings who wish to investigate research questions arising from clinical practice.

FBS runs 31 MRes and MSc programmes, with over 750 students enrolled per annum, which also emphasize research training and provide strong recruitment to further research degree programmes. Students spend at least 4 out of 12 months exclusively on a major research project, and graduate well-prepared for PhD or research posts.

Recruitment

Recruitment to PhD training is strong, based on broad marketing (mainly via the web), UCL's reputation, and active staff engagement with other HEIs, third sector organisations, and industry. Selection processes are criterion-based and geared to ensuring equality (e.g. decisions are taken by expert panels). **Most programmes are extremely competitive**: in 2012 the WT/MRC Neuroscience, MRC Mental Health, DClinPsy, CoMPLEX, and UCL-NIMH Neuroscience programmes received 70, 35, 30, 8, and 25 applications per place, respectively. This competitiveness yields outstanding students: for instance, all students recruited onto the WT/MRC Neuroscience programme in 2012 had 1st class degrees. Many applicants are international, further increasing the pool of excellent students from which applicants are chosen. The annual intake comprises ~20% overseas students.

Sustainable doctoral training programmes

Specific governance processes, reviewed regularly, are in place to ensure that our doctoral training is effective and sustainable, and that students are supported throughout their training.

All research students carry out their PhD under the auspices of the Graduate School which provides the quality control mechanisms for monitoring student progress. Each of the units in this submission has a Graduate Tutor 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 to their work, and provide support when they are in difficulties. All students are allocated to an experienced principal supervisor, while subsidiary supervisors have specific expertise in parts of the research being undertaken. 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 being allowed to become a primary supervisor. We have made active efforts to increase academic staff involvement in PhD supervision. Across FBS, the **number of research students per full-time academic staff member has increased by 30%** from 2.2 in 2007/8 to 2.9 in 2011/12.

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 records review meetings (including important milestones such as the MPhil to PhD upgrade) and discussions on academic (subject discipline), generic and transferable skills training. All students are expected to take advantage of the Graduate School Skills Development Programme, and are required to participate in this programme and/or appropriate departmental courses for a period equivalent to 2 weeks per year. There are over 220 different courses across the full range of skill domains defined by the Researcher Development Framework (RDF). Training courses and activities have been assigned a point value, and students are expected to accumulate 60 training points over 3 years, or 80 points over 4 years. They are

encouraged to take a broad range of courses across all the RDF domains. In the REF period **students in this UoA made over 4500 course enrolments**. The training record and point count is documented in the Research Student Log for review by the supervisory team and Graduate Tutors. 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. Of students enrolled in 2005-8, **261/298 (88%) completed their doctorates within the prescribed period, 4 years**. We anticipate improvement in this figure as not all of 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 Graduate Tutors to ensure that candidates are given adequate time and facilities for their doctoral studies and not disadvantaged by competing responsibilities. 65% of part-time students who commenced their studies in the years prior to the REF period completed their doctorate within the prescribed time.

Considerable emphasis is placed on **careers guidance** both via the Graduate School and the student's research group. The **success of these mechanisms is confirmed by first destination data**: of students graduating in 2011-12, 93% went on to full- or part-time employment and 6% to further study. Moreover, a high proportion of students continue in science: as an example, since its inception ~80% of graduates from the WT/MRC Neuroscience PhD programme have gone on to post-doctoral positions, and a further ~15% to science-related jobs (drug companies, scientific administration for charity or the civil service, patent agency, management consultancy, medicine, scientific publishing).

Integration into research culture

Doctoral students are an integral element of our research activity. The majority of students are involved in collaborative, often interdisciplinary, projects rather than stand-alone studies, and all are affiliated with specific research groups within the research departments and units contributing to this UoA. They therefore participate actively in the research programmes of these groups: attending research planning meetings, contributing to research articles, giving presentations of their work, and attending conferences in the same way as other junior research staff. 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. Typically, students present at one or two national and one overseas conference during their training, supported by funds from the Graduate School and individual research groups. A three day Postgraduate Psychology conference is held at Cumberland Lodge every year. The programme is organised by the PhD students themselves, providing an opportunity for intensive exchange with researchers outside the individual student's research group.

Funding is also available from the Graduate 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 computational modelling (MIT) and neuroimaging (UCLA) skills abroad. 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.

All the departments in this UoA run regular research seminar programmes at which students present their work. The annual UCL Neuroscience conference 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 symposium.

d. Income, infrastructure and facilities

Research income has increased by 27% during the REF period and grants totalling £263.8M have been won. We have continued to secure funding from the RCs and charities relevant to our research and have achieved strong growth in awards from BBSRC, EPSRC, and ESRC, the EU, and industry. In line with our RAE2008 strategy, we have seen **substantial growth in income for**

translational health research, spread across all FBS groups. The income has funded a very **substantial number of research fellows**. In the REF period we have been awarded fellowships worth £50.1M, including 16 NIHR, 17 clinical research training (including 7 MRC), 26 WT SRF/PRF/Investigator/Sir Henry Wellcome, 11 Royal Society, 5 Leverhulme, 11 ESRC, and 2 BBSRC fellowships.

Strategies for generating research income

Strategies for successfully competing for research funding operate at several levels. The Office of the Vice-Provost for research provides Research Facilitators embedded within the School who alert researchers to new funding schemes, co-ordinate large and interdisciplinary bids, provide support for early career and fellowship awards, and offer training on grant writing. The European Research and Development Office gives advice about EU programmes and promotes interaction with other EU groups. The UCL Neuroscience Domain within SLMS, and the BRC, also play lead roles in collaborative funding bids. At Faculty level, 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.

Major infrastructure investments and income

Highlights of unit-specific investments and income, and major future developments, are reported in our Research Strategy in section b above. Faculty-wide infrastructure developments during the REF period include the following:

- The **Clinical Neurosciences Centre** at 33 Queen Square and adjacent **neuroimaging suite** were opened at a cost of £26M, including £8M from the National Hospital Development Foundation. The Centre incorporates translational research activity, clinical activity (out-patients) and a 220 seat lecture theatre. The advanced neuroimaging suite, featuring three specialist MRI scanners and an interventional MRI BrainSuite system, provides an angiography, MRI and surgical facility, providing real time scanning of the brain and spine during surgery and offering innovative treatments to patients with complex neurological conditions.
- Redevelopment of **Queen Square House**: UCL acquired the freehold of Queen Square House from UCLH (£12M) in 2011 as part of the UCL Estates Strategy. This acquisition enabled an upgrade of the buildings infrastructure (£5M) and facilitated an options appraisal (£1M) on the redevelopment of the site with NHS partners (UCLH and Great Ormond St Hospital Trust). The planned £200M redevelopment of this site will permit future expansion of the clinical neurology and neuroscience research base in Queen Square and underpin the delivery of core elements of our research strategy. An early phase of this redevelopment will be the £30M relocation of the MRC Prion Unit from Queen Square House to the newly refurbished Courtauld Building, adjacent to the Sainsbury Wellcome Centre.
- Refurbishment of a floor of **Queen Square House** to provide a large microbiological containment level III facility to handle prions, tissue culture facilities, and general molecular biology laboratories (£3.3M, jointly funded by MRC/UCL). This includes robotic facilities and high throughput drug screening essential to our therapeutics programmes.
- Creation of a new **Neuroimaging Analysis Centre** through the complete refurbishment of the 3rd floor of 8-11 Queen Square funded by the National Brain Appeal and BRC (£1.5M), including medical imaging IT infrastructure, workstations, computer cluster, storage arrays, and wired (gigabit) and wireless network infrastructure.
- Refurbishment of the ground floor of 8-11 Queen Square by the National Brain Appeal (£1.2M) and the BRC (£0.5M) to create the **MRC Centre for Neuromuscular Diseases** which includes a neuromuscular experimental trials unit.
- The SRIF-3 funded (£12M) refurbishment of **Chandler House** in 2008 enabled co-location of four Research Departments (Language and Communication; Linguistics; Speech, Hearing and Phonetic Sciences; Developmental Science) with extensive speech, language, and developmental laboratories and an ERP facility including 6 sound-isolated recording and listening rooms, and a further two sound-isolated Faraday cages for auditory research involving EEG and ABR. A Kanazawa small-animal MEG system (£0.5M) was donated to the EI by the Kanazawa Institute of Technology.

- Staff in the Division of Psychiatry have been co-located on a single site in the refurbished **Charles Bell House** (£100K) in close proximity to the rest of UCL Neuroscience.
- Refurbishment of **Bedford Way** including creation of extensive state-of-the-art laboratory facilities. Phase 1 has been completed and Phase 2 commissioned.

Equipment and facilities

Investments of institutional resources, with external funding, have provided outstanding facilities for research, including:

- Extensive facilities for neuroimaging, including: an Agilent 9.4T pre-clinical MRI scanner; a Philips Achieva 3.0T MRI Scanner; three 3T Siemens Trio MRI scanners; a Siemens Avanto 1.5T MRI scanner; and a VSM MedTech MEG scanner. All facilities provide substantial IT, physics, radiography, and electronics support.
- A further 4 Siemens MRI scanners are available for research within the National Hospital, a 3.0T Trio, a 3.0T Skyra, and two 1.5T systems, one of which is combined with a neurosurgical and angiography suite for interventional MRI projects.
- Extensive facilities for microscopy; whole-body motion capture; eye-tracking; functional transcranial Doppler; gene sequencing; 3 TMS systems (MagStim BiStim, Magstim Rapids, associated coils); 2 frameless stereotaxy systems (BrainSight); equipment for capturing motor evoked potentials; an MRI-compatible EEG system.
- Extensive animal neuroscience facilities, as well as specialist laboratories for research in infant vision, neuropsychology (including an extensive range of test batteries), speech and language, cognitive development, and human-computer interaction, as well as numerous general-purpose testing facilities; specialised laboratories for human electrophysiology, crossmodal attention, and motor control studies, plus patient testing suites; a wet-lab and psychophysiology suite for psychopharmacology research, and developmental laboratories with advanced audio-visual facilities for attachment research.
- SLMS provides a large number of high quality cost recovered scientific platform services which are readily accessible to all researchers (e.g. genomics). Expert staff supporting the facilities contribute to protocol design. Within FBS there are specific scientific support services (e.g. engineering design facility; electron microscopy; statistics support).
- Underpinning these research facilities is **considerable investment in human resources**. Technicians (75) and research support staff (390 FTE) **have increased in number by 62%** over the REF period.
- UCL-wide library resources: UCL Library Services has invested in upgrading library facilities across UCL and in creating a number of flexible, IT-enabled spaces for individual and collaborative work. Other strategic investments include the launch of the new home for UCL research output, UCL Discovery, and the improvement of access to e-resources identified as necessary for research. UCL Library Services is also closely involved in the UCL Research Strategy and manages open access funding, including RCUK policy and WT funding.
- Queen Square Library, which was redesigned and refurbished (£1M) in 2010, offers specialist collections of international standing with a strong research focus, as well as facilities geared towards researchers, such as quiet, IT-enabled study space. Bids for new e-resources are made following recommendations from academic staff. A Research Resources in Medical History award from WT in 2011 is enabling preservation and cataloguing of the collections, which comprise the archives belonging to the National Hospital and IoN.
- The EI and Action on Hearing Loss Libraries are a collaborative venture including the NHS, based at the RNTNEH and constituting the largest specialist collection for audiology, deaf studies, and ear, nose and throat and otorhinolaryngologic medicine in Europe.
- The IoN Medical Illustration Unit supports researchers with production of websites, articles, posters, etc.

Operational infrastructure

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 £940K has been received for equipment, bridging, recruitment start-up packages and translational pump priming.

Co-ordinated research support is also provided by a range of services managed by the SLMS Research Support Centre (RSC). This includes a Research Coordinator Team which supports and coordinates internal research initiatives, particularly relating to the SLMS Research Domains (including Neuroscience), brings together communities by facilitating events and forums, and develops mutually beneficial relationships with external funding agencies. The RSC provides the management support function for the BRC's research themes. The UCL Translational Research Office (TRO), part of the RSC, supports the translation of basic and clinical research into therapies, techniques and medical products with therapeutic value. These aims are achieved through interacting with investigators, identifying translatable opportunities, advising on project progression strategy and accessing suitable funding. The TRO also provides project management expertise to steer programmes towards practical endpoints, and links investigators to the necessary resources (either internal or external) for projects at all phases, discovery, preclinical or clinical. The TRO has specialist knowledge of the translational funding landscape and administers the UCL Therapeutic Innovation Fund and the MRC-funded Confidence in Concept scheme.

The UCL/UCLH/Royal Free Joint Research Office (JRO), also part of the RSC, supports the work of the BRC, including its Neuroscience Programme, supported by a dedicated programme coordinator. The JRO clinical trial support team sponsor a number of major academic clinical trials and work in collaboration with UCL subject-specific clinical trials units such as PRIMENT.

The Institute for Clinical Trials and Methodology has been established in SLMS 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 one of the leading clinical trials groupings in Europe.

Research Governance

UCL has a set of research governance policies that underpin expectations about the conduct of research. The Code of Conduct for Research articulates UCL's expectations and defines action to be taken in the event that an individual is suspected or accused of research misconduct. The development of research governance strategy is the responsibility of the Research Governance Committee, chaired by the Vice-Provost (Research). UCL's Publications Policy ensures compliance with RCUK Open Access policy.

The JRO supports clinical research by providing timely, proportional yet safe research governance. There is a clear structure embodied in the R&D Operational Capability Statement, and standard operating procedures to guide both investigators and sponsors. A significant issue in clinical research is confidentiality and security in the use of patient data. The School's Information Governance Committee has set up an Identifiable Data Handling Service (IDHS) project to develop appropriate methods of storing identifiable patient data for research purposes.

e. Collaboration and contribution to the discipline or research base

For this section we have taken a quantitative approach, supported by examples. Data in this section were obtained from a comprehensive survey completed by all submitted UoA4 staff. In the REF period **55% of staff have given invited keynote lectures**; **67% have participated in conference organisation**, with **36% serving as conference programme chairs**; **22% have served on university research advisory panels** (e.g. ethics, research governance); and **74% have examined doctorates**.

54% of staff have been awarded scholarly fellowships or related awards. Major honours/prizes include: Nobel Prize (Rothman); OBE (Fonagy); CBE (Lund); FRS (Dolan, Friston, Hardy); FBA (Brewin, Woll); F Acad Med Sci (Birchall, N Burgess, Fox, Hardy, Lees, Maguire, Miller, Rees, Schiavo, Scott); Royal Soc Francis Crick Medal (Rees), Brit Psychol Soc Lifetime Achievement Award (Fonagy), Spearman Medal (Roiser, Viding), President's Award (P. Burgess); Exp Psychol Soc Mid-Career Award (Lavie, Shanks); Elizabeth Warrington Prize (Crutch, Fotopoulou); Patrick Wall Medal (Koltzenburg); Justine et Yves Sergent award (Price); Rumelhart Prize (Dayan); Brit Assoc Psychopharm Senior Award (Roiser); BA Wiley-Blackwell Prize (Viding); Int League Against Epilepsy Ambassador Award (M. Walker); Morgan Stanley/Daily Telegraph

Great Briton (Birchall); Royal Soc Med Clinical Neurosciences Section President's Prize (Rohrer); Brit Tinnitus Assoc Shapiro Prize (Schaette); US Alzheimer's Assoc de Leon Prize in Neuroimaging (Schott); Brit Med Assoc Jobson-Horne Prize for Otolaryngology (Schilder); Royal Soc of Apothecaries Farr Medal (Sampson); Lloyds Science of Risk Prize (Joffe).

51% of staff served on journal editorial boards. Senior roles include: Abels (*Syntax*); Ashmore (*Brain Res*); Blakemore (*Dev Cog Neurosci*); Carston (*Mind & Lang*); Chamorro-Premuzic (*Pers & Ind Diff*); C. Cooper (*Soc Psych & Psychiatric Epid*); Custers (*Psych Sci*); Devlin (*Brain & Lang*); Dolan (*J Neurosci*); Friston (*Cog Brain Res*, *NeuroImage*); D. Green (*Bilingualism*); Guinote (*Brit J Soc Psy*); Haggard (*Exp Brain Res*); Hardy (*Neuron*); K. Harris (*Trends Neurosci*); Hulme (*Psych Sci*); Joyce (*Psy Med*); Katona (*J Affective Disorders*); Kilner, Solomon (*PLoS One*); M. King (*Brit J Psychiat*); Kullmann (*J Physiol*, *Brain*); Linden (*Front Sys Neurosci*); Love (*Cog Sci*); Lund (*Rhinology*); Maguire (*Neuropsychologia*); Neeleman (*Nat Lang & Ling Theory*); Nevins (*Ling Inq*); Playford (*Clin Rehab*); Price (*J Neurosci*); Rees (*Brain*); Reilly (*Brain*); Rothwell (*Exp Brain Res*); Sander (*Lancet Neurol*); Schapira (*Eur J Neurol*); Schiavo (*J Cell Sci*); Scott (*Neuropsychologia*); Thompson (*Mult Scler J*); Vigliocco (*Psy Rev*).

32% of staff have served on national (Research Council or similar) or international grants committees, and **56% on learned societies/professional bodies**. Examples include: Birchall - MRC Regenerative Medicine panel; Blakemore - WT Society Activities Grants Committee; Brown - MRC Efficacy and Mechanism Evaluation Programme Board; Collinge - Council member, Royal Society; Gurling - WT Sanger UK10K DNA Sequencing Management Committee; Jahanshahi - Executive Committee, British Neuropsychology Society; Johnson - Executive Committee of the Academic Faculty of the Royal College of Psychiatrists; Killaspy - Member, Senior Clinical Academic Advisory Group, Athena SWAN programme UK; M. King - Member of the NIHR Health Technologies Assessment Programme Trials Board; Lemon - MRC Understanding Animal Research Advisory Board; Michie - MRC Methodology Board; NIHR Programme Grants Board; WT Influenza Scientific Advisory Group; Montague - China Frontiers of Science, National Academy of Science; Osborn - NIHR Research for Patient Benefit Board; Pilling - NICE Strategy Board; DH Expert Working Group on Improving Access to Psychological Therapies; Price - Scientific Advisory Board, Max PIanck Institute for Human Cognitive and Brain Sciences; Rees, Walsh - MRC Neuroscience & Mental Health Board; Rodd, Channon – Committee, Experimental Psychology Society; Rossor - MRC Ethics, Regulation and Public Involvement Committee, NIHR Strategy Board Alzheimer France Ministerial Advisory Group; Schilder - Divisional Co-Lead NIHR London Clinical Research Network; Spiers - WT Large Arts Awards Grant Committee; Thompson - European Charcot Foundation Board; WHO International Advisory Group for revision of ICD-10 'Diseases of the Nervous System'; Walsh - BBSRC Bioscience for Society Standing Committee; Wood - MRC Stratified Medicine panel; NIHR Bioresource Executive Committee.

Leadership roles include: Collinge - national, European Union and international Government advisory committees on prion disease; Fonagy - National Clinical Advisor for CYP IAPT; advisor to Ministers of State (Lamb, Burstow), Fox - Chair, Alzheimer's Society Research Advisory Committee; Joyce - Chair, British Neuropsychiatry Association; Koepp - Chair, American Epilepsy Society; Koltzenburg - Chair, Committee of Research of the European Pain Societies (EFIC); Petrides - Chair, International Society for the Study of Individual Differences; Pilling - member of the NICE Strategy Board; Reilly - President, British Peripheral Nerve Society; Revesz - President, Clinical Neurosciences Section, Royal Society of Medicine; Rossor - President, Association of British Neurologists; Saeed - President, British Society of Academic Otolaryngology; M. Walker - Chair, Joint Epilepsy Council of UK and Ireland.

In addition to the many specific collaborations noted in section b, **91% of staff have taken part in collaborative research involving other institutions**, and **52% in inter-disciplinary research**. **38% have taken part in collaborations with industry, commerce, third sector, or other users of research**, and **15% have taken part in collaborations for postgraduate research training**. Effective collaboration with industry is indicated by the award of 56 grants from industrial partners. International collaborations are thriving as indicated by the award of 92 EU and 89 non-EU grants in the REF period. **30% have sat on non-academic expert committees**.