Institution: University of Bristol

Unit of Assessment: 4 – Psychology, Psychiatry and Neuroscience

a. Overview

Bristol is a major centre for research in the cognitive and brain sciences (68.8FTE submitted, £51M External Research Income spend and 151 Doctoral degrees awarded in the assessment period). Expertise is broad-based which underpins our strong network of interdisciplinary collaboration and drives the integration of knowledge and discovery across this research area.

Bristol Neuroscience (BN) was founded by the University of Bristol in 2003 to provide cross-organisational strategic focus and to further strengthen interactions across the community for teaching, research and outreach activities. One indication of BN's success is that it has since become a model for other neuroscience organisations within the UK: similar schemes now exist at Oxford, Cambridge, UCL, Edinburgh and beyond.

BN brings together all academics included in this submission including staff working in the Schools of Physiology & Pharmacology; Experimental Psychology and Clinical Sciences (including the Laboratories for Integrative Neuroscience and Endocrinology and the Institute of Clinical Neurosciences). BN fosters a strong culture of high quality research, evidenced by the fact that over 15% of staff in this UoA were awarded highly competitive, externally funded fellowships during the review period. Research within this UoA is grouped into four cross-school themes: Cellular and Molecular Neuroscience, Systems Neuroscience, Psychological Science and Clinical Neuroscience. Significant cross-theme interactions also occur.

The research is underpinned by excellent research facilities including:

- The Wolfson Bioimaging Facility
- South West Dementia Brain Bank
- The new Bristol Clinical Research and Imaging Centre

The uniqueness of our cross-disciplinary research environment has resulted in the funding of flagship Masters and PhD training programmes by the MRC, Wellcome Trust, EU, BBSRC and ESRC (equivalent to a total of over 180 student years).

The activity returned within the submission is underpinned by Bristol University's broader world class research and it's particular strengths in health related research which is supported by the Elizabeth Blackwell Institute for Health Research which brings together researchers from health and non-health related disciplines to find innovative solutions for some of the most pressing health challenges of the 21st century. We actively maintain a mature network of strategic national and international collaborations to further strengthen our research capability.

b. Research strategy

BRISTOL NEUROSCIENCE

The central goal of contemporary cognitive and brain sciences is to develop coherent models that explain the mind and brain at every level: cellular and molecular, physiological, network, systems, computational, behavioural and social. Bristol's strength is a result of a recognition that major breakthroughs in this field are likely to come from multi-level collaborative research. The challenge is to integrate results from different research techniques and different disciplines to develop wide-reaching, coherent models that enable identification of the general principles and properties of the function of the mind and brain. BN's consistent mission is to provide the intellectual environment to achieve this goal by:

- enabling integrated research activity across the cognitive and brain sciences
- providing high quality research facilities
- ensuring that research is actively embedded in a broader world-class research environment

- driving strategic international and national collaboration

At an operational level BN has a major role in:

- determining research policy and strategy, including staff recruitment
- organising research meetings and workshops
- coordinating public engagement
- promoting neuroscience at Bristol both nationally and internationally

BN includes external members working within three regional NHS trusts (North Bristol NHS Trust, University Hospitals Bristol NHS Foundation Trust and Avon and Wiltshire Mental Health Partnership Trust), University of The West of England (UWE) and University of Bath.

BN has a long established track record of working with industry. BN activities in the review period has received externally financial sponsorship from: AstraZeneca, Boehringer Ingelheim, Charles River, Digitimer, R&D Systems, Eisai, Enzo Life Sciences, GEHealthcare, GSK, Janssen-Cilag, Medtronic, Millipore, Orion, P1Vital, Renishaw, Sigma-Aldrich, Tocris Bioscience, UCB Pharma. For a major part of the review period these interactions with industry were coordinated, and facilitated by **Severnside Alliance for Translational Research (SARTRE).** SARTRE was created in 2009 between the Universities of Cardiff and Bristol to combine and accelerate our efforts in translational research and to provide a focal point for interactions with external partners such as Bio-Pharmaceutical companies. SARTRE was funded by a £3.9M grant from the MRC and the Wales Office of Research and Development. SARTRE is now incorporated into the Elizabeth Blackwell Institute for Health Research.

In 2012 Bristol University founded a major new initiative, the **Elizabeth Blackwell Institute for Health Research (EBI)**. BN is now embedded in and supported by the EBI. EBI provides the opportunity and vehicle for BN to develop even wider cross-disciplinary links across the heath related area and into the natural and physical sciences. EBI runs a wide range of funding schemes. Since its foundation in 2012 members of BN have already received £440k in research funding from EBI.

Research policy and strategy

Leadership of research policy and strategy comes from the Director of BN (a post held in rotation by Apps, Gilchrist, Bashir and Love in the review period). The Director is supported by a Steering Group with representation from the breadth of BN activity. In 2009 BN began the process of developing a new 10-year strategic plan in consultation with the BN community, Schools and Faculties. The Bristol Neuroscience Strategic Plan was launched in 2010 and was subsequently adopted by the University. The strategy has five central objectives:

- Drive a translational agenda that ensures that fundamental neuroscience research delivers benefits to society
- Create a centre for translational neuroscience
- Establish a centre for neural dynamics
- Build on our international profile in neuroscience imaging
- Train the next generation of world-class neuroscientists

Research meetings and workshops

BN has organised a wide range of Workshops, Symposia in the review period that align with the BN Strategy as follows:

Drive a translational agenda that ensures that fundamental neuroscience research delivers benefits to society and *Creating a centre for translational neuroscience:* Dissecting Dementia (2008); Making brain matters matter in medicine and research (2009); Risk and reward (2009); Moving together for movement disorders (2010); Movement Disorders (2011); Sleep (2012, 2013); Deep Brain Stimulation and Circadian Rhythms (2013, in collaboration with University of Oxford);

Establish a centre for neural dynamics: Optogenetics (2011); Genetic neural circuit dissection (2011); Neurodynamics (2011); Nanoneuroscience (2012).

Build on our international profile in neuroscience imaging: Brain imaging in Bristol: Mathematical methods and analysis (2008); Mapping Cognitive Functions to Brain Regions (2009);

In addition, BN has organised a series of lectures: BN Evening Lectures & Lord Sainsbury Lectures (11 Lectures, speakers have included: Tipu Aziz, Clifford Woolf, Steven Rose, Alan Cowey, Richard Wiseman and Barbara Sahakian). BN Callosum Colloquia Seminar series (22 Seminars, mixed internal and external speakers).

In support of our strategic objective to drive a translational agenda, BN, in collaboration with Bristol University Institute for Advanced Studies, runs a Translational Neuroscience Research Fellowship scheme funded by a donation made via the University's Alumni Foundation. Using teaching buy-out, fellows are able to spend extended time in a local clinical setting. Four Fellowships have been awarded in the review period (Apps, Leonards, Robinson and Munafo).

BN plays an important role in coordinating public engagement and promoting neuroscience both nationally and internationally. Major activities in the review period include: Brain Awareness Week (Bristol, 2008-2014; >1000 visitors per year); Cheltenham Science Festival. (2008, 2009); The Creative Brain Autumn Public Lecture Series (Bristol, 2008-2009); Movies and the Mind film festival (Watershed, Bristol, 2009): a 4-day event with over 250 attendees/day; and our 10th anniversary festival (2013) – this was a major 2-day event with over 3000 visitors for the benefit of local schools, the general public and university staff, involving keynote presentations, an exhibition of neuroscience art and a wide range of hands-on demonstrations.

CELULAR AND MOLECULAR NEUROSCIENCE

A major strength at Bristol is the critical mass of expertise in cellular and molecular studies of **synaptic plasticity.** Activity in this area is coordinated by the Centre for Synaptic Plasticity (CSP) led by Collingridge. The Centre has received substantial funding from the MRC within the review period (£1.6M Centre award in 2008; £1.9M award to Jane in 2008; £1.9M award to Collingridge in 2013). Specifically, studies are directed at a greater understanding of how, where and why the brain modifies synaptic strength during normal function (in particular, during learning and memory) and in certain pathological states. The centre has four particular research foci: (i) medicinal chemistry, (ii) protein biochemistry, (iii) synaptic physiology and (iv) learning & memory.

Another major strength in this theme is work in **neuroendocrinology**. This area of research has also received substantial MRC support in the review period (£2.2M award to Lightman in 2012) In the last 5 years the research focus of these two significant groups has evolved, with emerging common interests in Alzheimer's and neurodegenerative disease, cell signalling and stem cells, stress and endocrinology, synaptic plasticity and repair, as well as integrative neuroscience and behaviour. In 2012 key members of the CSP were co-located within The Laboratories for Integrative Neuroscience and Endocrinology (LINE). This move was to support the BN strategic objective to develop a Centre for Translational Neuroscience by facilitating ongoing collaborations between members of CSP and LINE, most notably between Lightman, Cho and Collingridge. The strategy is to combine the expertise in synaptic physiology of members of the CSP, with the expertise of stress and environmental manipulation of members of LINE and to combine this expertise with a major collaborative research programme with Eli Lilly. The co-location of BN staff has already led to success in joint grants between Cho, Collingridge and Lightman on the effects of stress and glucocorticoids on glutamate receptor regulation and synaptic plasticity, and will provide further opportunity to link the research programmes of both LINE and CSP at neurochemical, electrophysiological and behavioural levels. A wide range of advanced neuroscience methods including state-of-the-art epigenetic, lentiviral, electrophysiological and imaging technologies are used to study changes in neuronal function. There is also considerable overlap with the following section on Systems Neuroscience as many PIs (e.g. Cho, Lightman, Murphy, Linthorst, Reul) integrate cellular and molecular approaches with *in vivo* and behavioural work. Both themes also have strong links with colleagues in Mathematics and Computational Science, with mathematical approaches driving work on the encoding and decoding of hormone pulse frequency (Lightman,

Walker and McArdle) and modelling of neuronal networks (e.g. Apps, Ashby, Bashir, Jones). External research income spend for this theme was £14.8M in the assessment period.

SYSTEMS NEUROSCIENCE

BN has a long standing track record in **whole animal *in vivo* (systems) research**. We actively drive an integrated, multidisciplinary, multi-method approach, taking discoveries at the cellular level from within the previous theme through to *in vivo* recording and behavioural analyses. This is a central feature of the CSP which spans Cellular and Molecular Neuroscience and Systems Neuroscience. Systems Neuroscience research is focused in four major areas: learning and memory; pain; central control of the autonomic system; and motor control. External research income for this theme was £18.7M in the assessment period.

A common interest and particular strength is the study of **brainstem circuits** in health and disease. It is this particular strength that has resulted in the BN strategic focus on establishing a centre for neural dynamics. We have therefore developed a major new initiative which is providing the infrastructure (see investment in Animal Services Unit below), academic staff (in particular the appointments of Brooks and Ashby) and shared equipment to develop and deploy advanced tools to selectively interrogate brainstem circuits that underpin a range of homeostatic mechanisms essential for life and the preservation of health. Advanced technologies and methods include: Viral transfection of CNS neurons; development of optogenetic methods; multi-array electrophysiological recording of neural network activity in behaving animals; longitudinal 2 photon *in vivo* imaging; and non invasive imaging of brainstem and spinal cord in humans. These and other advances rely on significant existing infrastructure including the Wolfson Bioimaging Facility, CRIC Bristol and the Animal Services Unit outlined below. The Wellcome Trust-funded PhD programme in Neural Dynamics, also discussed in more detail below, is an important additional mechanism to further build capacity in this theme. This is driving new collaborations across our different fields of expertise, e.g. bringing together researchers from the Psychological Science theme discussed below with autonomic neuroscientists to study brainstem mechanisms that could underlie the known link between neurogenic hypertension and AD.

PSYCHOLOGICAL SCIENCE

Research in this theme is organised into three focused research areas: Cognitive Processes; Brain, Behaviour, & Health; and Decision-Making & Rationality. External research income was £9.0M in the assessment period. The first of these research areas, **Cognitive Processes**, reflects the tradition of excellence in core experimental psychology within the UoA and links to studies of animal behaviour and cognition within the Systems Neuroscience theme. **Brain, Behaviour, & Health** was established within the review period to bring together excellence in neuropsychology and the psychological aspects of health-related behaviour and to strengthen links to Clinical Neuroscience. Brain, Behaviour & Health also has well-established external links with industrial partners (including GlaxoSmithKline and Unilever) and is a member of the UKCRC Centre of Public Health Excellence in Tobacco Control. The **Decision-Making and Rationality** research area represents a strategic decision to focus on an emerging field of research and align us with the strategic priorities of our key funders. It is built around a £1.6M EPSRC multidisciplinary grant which brings together experimental psychology and internationally leading theoreticians at the University of Bristol (McNamara FRS and Leslie in Mathematics, Houston FRS in Biology and Bogacz in Engineering). External links include the 'Safe Human Robot Interaction' project which links us to the Bristol Robotics Lab (BRL). The BRL is a partnership between the University of Bristol and UWE, and is the largest multi-disciplinary robotics research facility in the UK. Additional work on animal and human camouflage provides a strong link with the School of Biological Sciences and researchers in this area have been physically co-located to deepen the collaboration. The development of the Bristol Clinical Research Imaging Centre (CRICBristol) described in more detail below, reflected the strategic need identified by this group in RAE2008 (UoA44) to broaden its portfolio of research methods to include MRI based methods as well as a commitment to the broader BN strategic objective in imaging. This is an area in which we are actively building capacity.

CLINICAL NEUROSCIENCE

The Institute of Clinical Neuroscience (ICN) is a major focus for translational research within the UoA and thus central to BN's strategic objective to drive a translational agenda. The ICN was formed in 1999 and contains four research groups: the Dementia Research Group, the Multiple Sclerosis and Stem Cell Group, the Functional Neurosurgery Research Group and the Bristol Neonatal Neurology Group. Most of the academics also hold clinical appointments within the NHS which enhances the focus on clinical impact and relevance. External research income for this theme was £8.7M in the assessment period.

The **Dementia Research** Group uses molecular genetics, biochemical, cell culture and neuropathological approaches for *ex vivo, in vitro* and animal model-based studies, and cognitive tests and neuroimaging for studies in patients, to research Alzheimer's disease (AD), other dementias and normal cognitive function. It incorporates the South West Dementia Brain and DNA Bank (see below). The **Multiple Sclerosis and Stem Cell Repair** Group is interested in the process of tissue repair in the brain and spinal cord, particularly in relation to multiple sclerosis, and the development and testing of novel treatments designed to enhance and stimulate repair. The **Functional Neurosurgery** group is engaged in the development, optimisation, commercial production (with industrial partners) and experimental and clinical testing of a range of surgical devices for the treatment of neurological disease, ranging from artificial cervical joints; through computer-directed robotic devices for highly accurate MRI-directed placement of stimulator probes and catheters; to recess-stepped, ultrafine, chronically implantable ports and catheters for convection-enhanced drug delivery. The Bristol Neonatal Neurology Group is interested in (i) hypoxic-ischaemic brain injury in the term infant and (ii) intraventricular haemorrhage (IVH) in the premature infant. Our strategy to develop ICN over the review period has been to build research strength in key areas through new appointments (e.g. to enhance the Dementia research group through appointment of Coulthard) and to develop new translational collaborations with other research groups within BN, notably imaging (Kauppinen), and basic science (Apps, Jones, Mellor). ICN is now running its first full clinical trial in dementia (Kehoe) and is creating the facilities to significantly build capacity in this area (see below).

FUTURE STRATEGIC AIMS AND GOALS

We have made significant progress already against the objectives as set out in the BN strategic plan and we have ambitious plans to make further major progress in all 5 areas.

Drive a translational agenda that ensures that fundamental neuroscience research delivers benefits to society. BN provides an excellent environment and support structures to deliver this objective. The new CRICBristol is providing additional opportunities as a centre in which to carry clinically intensive research with patients and healthy volunteers. Following the success of BN's Translational Fellowships we intend to introduce a new fellowship scheme to allow clinical scientists to spend time in a basic neuroscience laboratory. The University (with funds raised through the Campaigns and Alumni Relations Office), local medical charities and North Bristol NHS Trust, have together committed over £4M for the development of a dedicated ICN clinical research and patient assessment facility (work already commenced), to host clinical trials and to facilitate the translation of advances in neuroscience research into clinical practice.

Create a centre for translational neuroscience. We have moved key members of the CSP to LINE in order to foster integration and this has already led to substantial new grant funded activity. We are currently working with Cambridge University and the Eli Lilly Centre for Cognitive Neuroscience (CCN) to form a 3-way partnership to support drug discovery research for neuropsychiatric disorders including dementia.

Establish a centre for neural dynamics. Development of this project is well advanced with both a Wellcome Trust funded studentship programme and investment in staff and infrastructure. Refurbishment work funded by the University has provided dedicated *in vivo* 2 photon confocal imaging facilities and we have developed a major initiative to physically collocate cognitive,

sensory, motor and computer neuroscientists to study the neural circuit basis of behaviour and in particular, the importance of dynamic interactions within and between different brain regions We are already in consultation with the Wellcome Trust about providing major funding for the next ambitious stage in this initiative via a Strategic Award.

Build on our international profile in neuroscience imaging. The Wolfson Bioimaging Facility, the Nuclear Magnetic Resonance Facility and the new CRIC Bristol together give us excellent neuroscience imaging facilities from the cell to the whole brain. We have recently received major capital funding from the MRC (£2.7M with an additional £1.1M from the University of Bristol) to build an PET, μCT and MRI animal imaging centre which will particularly support our work in neonatal neuroscience and provide a integrated imaging portfolio across scales and species.

Train the next generation of world-class neuroscientists We have a broad set of training programmes (see below). Our focus in the coming years will be to grow capacity in clinical neuroscience research training.

c. People, including:

i. Staffing strategy and staff development

We are fully committed to a staffing policy that, via the career development of all staff, will result in the generation of world-class research. Within the University of Bristol, staff are appointed and managed in Academic Schools. There are, however, a number of University-level common policies and practices that support staff development. These include:

- All staff are members of coherent research groups which are large enough to provide a strong research environment for advice and collaboration
- Research groups have regular meetings that include discussion of developments in the area as well as the presentation of new data. These are supplemented by weekly external and internal School seminars to generate a strong research culture
- The compulsory annual staff review and development process gives all staff an opportunity to assess their career progression and training needs with their Head of School
- All new members of staff have substantially reduced teaching and administrative loads in their first year to allow them to establish their research and all are assigned a senior academic research mentor
- The University has a strong programme of research support and training that includes external training by the research councils and industry
- In recognition of our commitment to advancing the careers of women in science one of the major schools in this submission, the School of Physiology & Pharmacology, holds a Athena Swan Silver Award and the University holds a Bronze award.

Researchers working in the Clinical Neuroscience group in particular combine NHS responsibilities with clinical research and hence are working continuously at the impact interface between neuroscience research and patient care. As a result of this, members of NHS staff also become part of the neuroscience research community and we have a strong commitment to issuing honorary University of Bristol contracts to these members of staff so that they have full access to University facilities and become fully integrated into the research community.

The University of Bristol is a signatory of the *Concordat to Support the Career Development of Researchers* and is fully committed to working towards the associated principles. In recognition of the University action plan to deliver on the concordat the University was awarded the HR Excellence in Research badge by the EU Commission in October 2010.

The University of Bristol has a central Research Governance Team with well-established processes to provide support and training to all researchers. The team ensure that all studies are registered with the appropriate authorities (including compliance with the Human Tissue Act 2004) and have appropriate ethical approval. The Animal Services Unit (see below) also runs Home

Office licence courses (modules 1-4) and local ethical review for animal research project licences.

Investment in staff

To build research capacity in the UoA we have invested in a number of academic appointments. To build on the UoA's strength in *in vivo* neuroscience research we appointed 3 **RCUK Fellows** (Balthasar in 2011, Jones in 2010 and Robinson in 2010). All three are now permanent members of academic staff. In 2011 we appointed Ashby to a lectureship from NIH (USA), bringing increased expertise in two photon *in vivo* confocal microscopy. This expertise filled an important gap in our imaging portfolio as we now have capacity ranging from cellular (Wolfson Bioimaging Centre), through whole animal to human (CRICBristol). Longitudinal two-photon imaging also complements our existing strengths in chronic electrophysiological recording in awake animals. Three appointments were made to support MRI Neuroscience imaging in CRICBristol: a Chair in Imaging (Kauppinen), a Senior Research Fellowship (Brooks) and a Research Fellow (Thai). Mellor and Whitcombe were appointed (in 2009 and 2013) to further strengthen our research in synaptic plasticity. We made two appointments to strengthen are social cognitive neuroscience (Park, Turk) and three in the central area of human cognition, one in the psychology of language (Davis, in 2013), one in human memory (Lewandowsky, in 2013) and one in perceptual decision making (Ludwig). We also have two **proleptic appointments:** Pickering will be appointed in 2015 and Jones in 2016 (following their Senior Research Fellowships, see below); this is an important part of our translational neuroscience strategy, as was the appointment of Randall to a Chair in 2012, formerly sponsored by Wyeth/Pfizer.

New Investigator awards during the review period include Hodge (2008, BBSRC), Robinson (2008, MRC), Ashby (2011, MRC) and Walker (2013, MRC). **Research Fellowships** were awarded to over 15% of staff in this UoA: Bashir (Leverhulme Fellow 2013-14); Balthasar (BHF Intermediate Basic Research Fellow, 2006-2010 and Lister Institute Fellow, 2007-2012), Brooks (MRC Research Fellowship, 2011-2013), Gilchrist (BBSRC Research Development Fellowship, 2010-2013), Jones (MRC Senior non-clinical Research Fellowship, 2011-2016); Laws (Wellcome Trust Fellow, 2008-2009), Ludwig (EPSRC Advanced Research Fellowship, 2008-2013), Mellor (Wellcome Trust New Investigator Award, 2013-2019); Pickering (Wellcome Trust Senior Clinical Research Fellowship, 2009-2014).

ii. Research students

Our cross-disciplinary research environment is ideal for research training and this is reflected in the following **flagship training programmes** delivered by the UoA:

MRC capacity building 4-year PhD programme '*In vivo* Neuroscience: from networks to homeostasis'. This award was made in 2009 to support research within the field of whole animal *in vivo* systems neuroscience in health and disease. It funds 10 students (plus 2 university scholarships) between 2009-2014. The award was supported by top-up funds from the Integrative Pharmacology Fund and has a total value of £1.1M.

Wellcome Trust 4-year PhD programme in 'Neural Dynamics: from synapses to systems in health and disease'. This award was made in 2011 and funds 20 students between 2011-2015 (plus 3 university scholarships). The award has a total value of £2.9M. This four-year PhD programme sees researchers and students working together on a new approach to neuroscience, which draws on the expertise of clinical and basic neuroscience, as well as theoretical disciplines such as computer science, engineering and mathematics to co-supervise research projects. Students returned in this UoA have also been funded by the £4.5M Wellcome Trust 4-year PhD programme in Dynamic Cell Biology.

The EU Marie Curie International Training Network PhD programme in neuroscience. This training programme in *Synapses: from molecules to brain and disease* is a partnership funded by the EU to support training across 6 Europe Institutions including Bristol (total value of award €5M). It funds 23 early-stage researchers (4 in Bristol) for 3 years from 2010-2013. The programme offers students the opportunity for 6-month placements with one of the industrial partners, and for attending workshops run by each of the academic partners.

BBSRC South West Doctoral Training Partnership (SWDTP) is a PhD training partnership between the University of Bristol and the Universities of Exeter and Bath, along with Rothamsted

Research. It is funded from 2012 to 2014 for 19 students per year (12 in Bristol). Its focus is on two main areas: Food Security, and World-Class Bioscience. The training partnership offers students a four-year research-based PhD programme, which includes some core teaching and two short research projects in the first year. A wide variety of co-supervised PhD projects are available to students including ones in the cognitive and brain sciences. So far 3 students within the remit of this UoA have been funded.

ESRC South West Doctoral Training Centre (SWDTC) is accredited by the ESRC to provide postgraduate research training in the social sciences. It comprises the Universities of Bristol, Exeter and Bath and has been allocated 41 ESRC 1+3 studentships annually. Students from all areas of psychology can be funded, and all PhD students in the participating schools have access to all of the training opportunities offered across the SWDTC.

BBSRC Masters in Systems Neuroscience. In 2010 we set up a new MRes in Systems Neuroscience that provides students with intensive research training in state-of-the-art *in vivo* neuroscience techniques combined with advanced analytical methods. To launch the new programme BBSRC funded 12 x 1 year studentships (£271k).

All research students take part in the mandatory Annual Progress Monitoring Process. This assesses the academic progress of the students using a 'mini-viva' and a written research summary, as well as identifying specific training needs. All students have at least two supervisors.

Within the Schools, where undergraduate teaching occurs, there is a particular focus on encouraging our best undergraduates onto a research career path. Our Undergraduate Research Apprenticeship Scheme provides an opportunity for first year students to volunteer to work within a research laboratory. Currently 20 students are participating in this scheme. For many years we have hosted two undergraduate level ***in vivo* training courses**: one for pharmacology students (funded by the British Pharmacological Society and the pharmaceutical industry), and the other as part of a national scheme to attract young talent to the field of *in vivo* research (funded by the MRC, Wellcome Trust, BPS, Physiological Society and Integrative Pharmacology Fund). Apps is chair of the national steering group and in 2012 funding of £345k was obtained from the Wellcome Trust, MRC and BBSRC to expand the scheme to 5 courses per year, run at Bristol, KCL, Glasgow and Strathclyde.

d. Income, infrastructure and facilities

Income

Overall external research income spend in the assessment period has been £51M, equivalent to £744K per FTE. We have maintained a sustained level of funding across the assessment period with over £10M of external research income spend in every year. There is also substantial research income in all four research areas (see above). The funding sources within the UoA are broad based: £27.9M spend from the full range UK Research Councils and Royal Society, £16.4M from Charities (including the Wellcome Trust) and £6.8M from Industry, EU and other funders. The type of funding has also been diverse and included Project, Programme and Centre Grants; Postgraduate Programmes; Fellowships; Consultancies and Industrial contracts.

A number of major University Core facilities are used by researchers from across the UoA. The first three represent the infrastructure required to deliver BN's strategic objective in neuroscience imaging.

Wolfson Bioimaging Facility. Established in 2008 this microscopy facility is located in the Medical Sciences Building, University of Bristol and builds on the internationally leading facilities of this kind that have been available in Bristol since the 1990s. It is unique in the UK because it fully integrates Light and Electron Microscopy, with new FEI electron microscopes sitting side-by-side to the latest Leica and Perkin Elmer confocal and TIRF microscopes; it is particularly well set up for live cell imaging and for correlative light and electron microscopy (CLEM). The facility provides both the latest-state-of-the-art, as well as more routine facilities for both modalities. Total capital investment in the facility in the review period was £2.2M.

The Bristol Clinical Research and Imaging Centre (CRICBristol). This is a key development

since the last RAE involving £6.4M of investment. CRICBristol is a collaboration between the University of Bristol and the University Hospitals Bristol NHS Foundation Trust to provide new research dedicated facilities that can be used with both healthy and patient research volunteers, including children and babies. The facilities include a 3-Tesla Siemens Magnetron Skyra MRI scanner (funded by the Wolfson Foundation), recovery and anaesthesia suite, a two bed dedicated sleep laboratory and 4 clinical research rooms. Unusually for a research dedicated MRI imaging centre in the UK, all rooms have full clinical support for infants, children and adults including medical gases to allow us to build on our strong Clinical Neurosciences. The University has supplemented this investment with 3 new academic posts and 4 support posts. Specialist infrastructure was installed with CRICBristol to take full advantage of Bristol's High Performance Computing Facility (total investment in the review period £10M, with a further £3M in progress).

Nuclear Magnetic Resonance Facility. This facility based in the School of Chemistry underpinned a significant proportion of the work carried out by the Centre for Synaptic Plasticity. For example, work on excitatory amino acid receptor ligand development is unique in UK academia for the synthesis of biologically relevant molecules. This facility has received significant investment in the review period including £1.2M for 4 new NMR machines (Varian 400, 500A, 500B and 600 machines).

South West Dementia Brain Bank and DNA Bank (SWDBB) is one of the largest such resources in the UK, with over 900 brains and several thousand clinical samples of DNA and RNA. It is part of the *Brains for Dementia Research* ABBUK-funded network and provides tissue, DNA, and RNA to many other groups in the UK and abroad. The SWDBB is housed in the modern, purpose-built John James laboratories at Frenchay Hospital.

Animal Services Unit (ASU). *In vivo* facilities at Bristol include a barriered breeding facility for rodents, of around 1000m^2. This facility currently houses around 120 lines of genetically modified mice. Within the main research area, there are facilities totalling approximately 2000m^2. These are multi-use facilities, but a significant proportion (around 50%) are used by neuroscientists. Facilities include animal holding space, surgical procedure rooms and behaviour rooms (including a water maze amongst a wide range of other behavioural set ups). Behaviour rooms are designed to also allow long term electrophysiological recording studies in rodents and uniquely, also cats. Dedicated procedure rooms are available for the use of viral vectors up to Category II, and large animal facilities also exist, allowing translational neuroscience work (e.g. development of direct CNS delivery systems). Total direct spend for the unit is £2M per year (~50:50 consumables and staffing) with staffing levels in 2013 of 28 FTE. Attributed costs amount to a further £3.3M annually. Around 600m^2 of space across the *in vivo* facilities are undergoing major refurbishment at a total estimated cost of around £3M.

Laboratory refurbishment. Across the Schools represented in this submission there have been extensive basic laboratory refurbishment and upgrades in the review period, notably a £1.2M investment in the School of Physiology & Pharmacology. Within the School of Experimental Psychology external equipment funding of £390k from the Wellcome Trust (plus an additional £70k from the University) supported the creation of a *Bristol Vision Institute Movement Laboratory*. This 58m^2 space houses a facility to study the role of vision in active motor behaviour. The *Nutrition and Behaviour Unit* has been newly refurbished and expanded during the assessment period (106m^2) and includes a large research kitchen, plus rooms for testing individuals or groups. The School also houses dedicated smoking labs to support the work of our Tobacco and Alcohol research group; a CO_2 challenge laboratory to investigate the effects of anxiety of cognition; eye tracking systems and 3 state-of-the-art EEG laboratories; the Bristol Cognitive Development Centre, a 39m^2 suite of reception rooms and testing space designed specifically for research with children, and which also hosts a database of over 2000 volunteers.

LINE, which occupies the Dorothy Hodgkin Building, custom built for this purpose in 2000, has particularly good facilities for microscopy, including several wide field fluorescence microscopes, a two-photon confocal microscope and an InCell 1000 high-content imaging platform. The latter was the first equipment of its kind in academia in the UK and has underpinned several collaborative projects (notably between McArdle and Lightman, Allen, Lopez-Bernal or Coward). Joint funding from our two medical faculties covered the refurbishment costs (£150K) for the move of key CSP members to the Dorothy Hodgkin Building in 2012.

Within the Clinical Neurosciences, the Dementia Research Group is housed in the purpose-built John James laboratories and the recently-refurbished BRACE Clinical Research Facility. The Multiple Sclerosis and Stem Cell Repair Group is based in the newly refurbished Burden Neurological Institute laboratories. The Bristol Neonatal Neurology Group is based in the two neonatal intensive care units at St Michael's and Southmead Hospitals and the Neonatal Neuroscience Laboratory in the neighbouring preclinical Veterinary School. From mid-2014 Clinical Neurosciences will be located in purpose-built new research facilities at the new Southmead hospital: a new, expanded laboratory (an investment of £1.5M) and an adjacent dedicated ICN Clinical Research Facility (an investment of over £4M).

Members of this UoA play key roles in the leadership of these facilities: Gilchrist as lead academic in the development of CRICBristol and now Co-Director of the Centre; Love as Director of SWDBB; Scolding as Director of the ICN; Lightman as Director of LINE and McArdle as a member of the Wolfson Bioimaging Steering Group.

e. Collaboration or contribution to the discipline or research base

Within the University and beyond there is a rich pattern of collaboration to support activity in the UoA. A number of organisations support this cross disciplinary integration.

The recently established **Elizabeth Blackwell Institute for Health Research (EBI)** integrates health related research from across the University. Neuroscience is one of the EBI's three major research themes (along with Cardiac Science and Population Health). For example, EBI coordinated the recent £12M EPSRC funded SPHERE (Sensor Platform for Healthcare in a Residential Environment) project. Gilchrist and Munafo from this UoA were both applicants on the grant which will further build the UoA's collaborations with Engineering and Computer Science.

Bristol Health Partners (BHP) is a collaboration between the four Bristol NHS Trusts and the city's two universities and its local authority. BHP has a programme of forming Health Integration Teams (HITs) which are cross-organisation, interdisciplinary groups set up to tackle major health priorities in an integrated manner. Within the UoA there are currently two HITS. The first is *Joint Working for Dementia* led by Coulthard and the second is *Parkinson's Disease and other movement disorders* led by Whone. These HITS extend and strengthen the UoAs existing collaborative network with clinicians and builds translational links with basic scientists.

The **Bristol Vision Institute** brings together researchers from across the University with an interest in biological and artificial visual systems. It is a recognised University research theme with over £8M in grant funding. It hosts fortnightly seminars, a major annual public lecture and an annual graduate conference with UWE and Cardiff. It provides an important bridge between researchers in this UoA (notably in the Psychological Science Group) and both Engineering and Biological Sciences.

Members of the UoA are playing a significant role in the recently announced £23M **MRC Integrative Epidemiology Unit**. For example Munafo is an applicant on the grant and his time is now 50% funded by the Unit. This further enhances the UoAs links with Social and Community Medicine, including our role in designing the cognitive assessments that formed part of the Avon Longitudinal Study of Parents and Children (ALSPAC).

In the Region, BN has coordinated Bristol's involvement in **the Bristol Cardiff Neuroscience Collaborative Network (BCNCN)** which was launched in 2006 to enable greater collaboration between Cardiff and Bristol neuroscientists. BCNC activities have included focus groups in specific areas of neuroscience, joint meetings, lab exchange visits, tours of facilities and arranging training days. A significant BCNC activity is the Young Neuroscientists' Day (over 200 attendees) held in 2007, 2008, 2010 and 2012. BCNC also runs a Travel Prize Scheme to support early career scientists and inter-institutional collaboration (9 awards were made in the review period).

The University of Bristol **Institute for Advance Studies (IAS)** provides another important mechanism to support international collaboration. In the review period, the prestigious IAS Benjamin Meaker Visiting Professorships have been awarded to:

- Leventhal, (2009) University of Southern California, USA, on *Genetics of tobacco withdrawal*
- Pasch (2010) University of Texas at Austin, USA, on *Adolescent risk behaviours: Patterns and prevention of the co-occurrence of behaviours*
- Chen, (2012) City University of Hong Kong, on *Analysis and control of complex evolving networks*
- Thomson, (2012), Brock University, Canada, on *Establishing a second language (L2) speech laboratory for measuring L2 pronunciation and oral fluency development*
- Cockburn, (2013) University of Canterbury, NZ, on *Improving skills learning using shape changing devices*
- Orchard, University of Waterloo, Canada (2013) on *Neural engineering the cognitive models of decision-making.*

The IAS have also worked together with BN to deliver the Translational Neuroscience Research Fellowships (Apps, Leonards, Robinson and Munafo) as discussed above and provided Fellowships to members of the UoA to allow them to concentrate full time on research for a year (Bowers, Gilchrist).

The **World Wide University Network** (WUN) of which the University of Bristol is an active member coordinates a number of major international collaborations. For example, one network that has been actively supported by WUN is in Learning and Memory and includes collaborators from Bristol, Zurich, University of Western Australia and Warwick. In 2011 Bristol and Chonnam National University, in South Korea, a member of the WUN network, launched the Bristol Chonnam Frontier Lab, which has secured £2M of funding from the Chonnam National University Hospital to tackle neurodegenerative brain diseases such as Alzheimer's and Parkinson's.

The recently announced **Great Western 4 (GW4)** partnership between Cardiff, Bath, Bristol and Exeter Universities will build on existing collaboration across these four local Russell Group Universities. There have already been a number of local UoA linked meetings to identify new areas of collaboration, for example in Psychology.

Members of the UoA are actively involved in **decision-making for a wide range of major national and international funders,** including committees for the BBSRC, MRC, ESRC, NIHR, Wellcome Trust, Parkinson's UK, Royal Society, US Academy of Medical Sciences, European Brain Research Institute, Gordon Research Conferences, HEFCE RAE 2008 and REF2014. Of particular note are the following appointments:

- Collingridge (2008 -) Member, Royal Society Medals and Awards Panel
- Collingridge (2009 – 2012) Member, Academy of Medical Sciences Sectional Committee (Three Panel)
- Collingridge (2010 -) Member, European Brain Research Institute, International Advisory Board
- Jarrold (2007-2010), Honorary Secretary, Experimental Psychology Society
- Kauppinen (2008-2010) Member of Council, Gordon Research Conferences
- Lightman (1987-) Chairman, Neuroendocrinology Charitable Trust
- Love (2003–2010) Secretary General, International Society of Neuropathology,
- Love (2013–) Director of the UK Brain Bank Network
- Love (2012−) President, British Neuropathological Society,
- Munafo (2010-) Council Member, British Association of Psychopharmacology

The following major **Awards of Distinction** were made in the review period to members of the UoA:

- Balthasar (2008), Physiological Society GL Brown Prize Lecturer
- Brunstrom (2011), The Society for the Study of Ingestive Behavior's Alan N. Epstein Research Award
- Cho (2011), Royal Society Wolfson Research Merit Award
- Collingridge (2008) The Santiago Grisolia Prize
- Farrell (2009), biennial Paul Bertelson Award, European Society for Cognitive Psychology
- Gilchrist (2012). Fellowship of the British Psychological Society
- Henderson (2010-2014) Elected First Vice President, International Union of Basic and Clinical Pharmacology, awarded 2013 Vane Medal by the British Pharmacological Society.
- Henderson (2009) Fellow British Pharmacological Society
- Hood (2013) British Psychological Society Public Engagement and Media Award
- Lewandowsky (2013) Royal Society Wolfson Research Merit Award
- Lightman (2011) Honorary Member British Society for Neuroendocrinology
- Love (2012) Asao Hirano Award from the American Association of Neuropathologists.
- McArdle (2013). Fellowship of British Pharmacological Society
- Munafo (2012) British Association of Psychopharmacology: Psychopharmacology Award
- Robinson (2012) Elected Fellow of the British Pharmacological Society
- Thoresen (2010) elected to the Academia Eurpaea

Members of the UoA held **editorships** on over 70 academic journals in the review period and have been involved in organising a wide range of local, national and international **conferences or workshops**, including:

- Alzheimer's Research Trust 9th Annual Conference (2008)
- UK-Korean International Symposium (2008-2013)
- British Society for Endocrinology Annual Meetings (2011-2013)
- 10th European Congress of Neuropathology, Edinburgh (2012)
- 16th annual meeting of International Society of Biomagnetism, Sapporo, Japan, (2008)
- European Congress of Neuropathology, Athens, (2008)
- 9th World Congress on Neurohypophysial Hormones, Boston, USA. (2011)
- Physiological Society International meeting (2009)
- European College of Neuropsychopharmacology, Florida, USA (2011)
- 8th International Conference on Engineering Psychology and Cognitive Ergonomics, San Diego, USA, (2009);
- Society for Research on Nicotine and Tobacco Europe, (2009-2010).