Institution: University of Bristol
Unit of Assessment: 4: Psychology, Psychiatry and Neuroscience
1. Unit context and structure, research and impact strategy

1a. Overview of research structure

The University of Bristol (UoB) has a distinguished tradition as a major centre in cognitive and brain health research (this UoA4 submission comprises 83 researchers, 77.34 FTE submitted, £63M of research income spend and 255 Doctoral degrees awarded in current assessment period). A core part of UoB's overarching research mission is the comprehensive bidirectional study of the full translational health pathway spanning from molecules to populations. We achieve this collaboratively and through interdisciplinarity across all biomedical research activities that are returned in UoAs 1, 2, 5 and 6 and across multiple disciplines including those submitted in UoAs 8-12 of this REF submission. This integrated approach enables us to tackle major global societal challenges, including mental health and neurodegeneration, and respond with agility to new challenges including COVID-19.

The establishment of a single Faculty of Life Sciences (FLS) has united all biological sciences, and this, along with restructuring of our Faculty of Health Sciences (FHS), promotes greater synergy for cross-university interdisciplinary research for staff returned in both Neuroscience (UoA4) and Biomedical Science (UoA5). Research strategies and appointments are supported by an overarching Health and Life Sciences Research Strategy Committee to maximize added value and exploit key and novel interdisciplinary scientific interfaces. Interdisciplinarity is further fostered by our University Research Institutes (URIs) and Specialist Research Institutes (SRIs), each chaired by a PVC and led by a Director supported by a board composed of all faculty Deans. The establishment of the URIs, namely, the Cabot Institute (environment), the Jean Golding Institute (data), the Brigstow Institute (living and being) and the Elizabeth Blackwell Institute (health), which presciently anticipated the establishment of UKRI, has proven a highly effective mechanism for creating a step-change in UoB research activity by bringing topflight researchers from across UoB into emerging interdisciplinary fields of importance to UoA4 but not bounded by it.

Research related to this UoA is delivered with strong commitment to *equality, diversity and inclusion* (EDI) and career development of all staff, especially early career researchers (ECRs). Our submission represents activity through three schools across FLS (the School of Physiology, Pharmacology and Neuroscience (PPN, led by **Piggins**) and the School of Psychological Science (PS, led by **Gilchrist**, Fellow of the British Psychological Society) and FHS (Bristol Medical School, BMS, led by Blom (UoA2)). UoA4 consists of 83 (27 PPN, 30 PS, 26 BMS) researchers, (providing a total of 77.34 FTE staff) 31% of whom are female, 6% staff are ECRs, and 18% of whom are clinical academics). Major achievements during this REF cycle (2014- 2021) include:

- Strategic leadership: creation and alignment of FLS and FHS and subsequent restructuring of Bristol Neuroscience (BN) activity (that represents UoA4), following external review, to refine neuroscience research priorities and direct future activities.
- Significant clinical links across the region, driven by **Wynick** as Director, Bristol Health Partners AHSC and Joint R&D Director for University Hospitals Bristol and Weston NHS Foundation Trust and North Bristol NHS Trust.

- Advancing knowledge: More than 1950 publications, with over 440 in top 10% (Scopus® Indexed journals) most cited worldwide.
- Increased research income: Grant spend led by UoA4 PIs totals £63M in the current period (up from £51M in REF2014), including 5 neuroscience Wellcome Trust Investigators in UoA4, and 2 in UoA5. In 19/20, 37% of grants were awarded to female researchers.
- Increased research capacity: The recruitment or promotion of 15 scientific leaders (9 women and 5 ECRs) has increased the FTEs returned in UoA4 and supported an upward trajectory for income per FTE (£0.83M/FTE now compared to £0.77M/FTE in 2014) and recruitment of exceptional ECRs.
- Increased research quality: UoA4 has been central in Responsible Research and Innovation (RRI) both in UoB and nationally. **Munafò** co-directs the UK Reproducibility Network.
- Investment in people: We have developed fully integrated training programmes that benefit staff and students at all levels equally and cater for both basic and clinical scientists. Bespoke career development opportunities are provided through the UoB Vice Chancellor Fellowships (3 in this UoA funded at £200k per award), and the Great Western 4 (GW4, a formal alliance with the Universities of Bath, Exeter, and Cardiff) Clinical Academic Training (CAT) pathway (£5.1M Wellcome Trust). Doctoral awards have risen to 255 from 151 in REF2014.
- Diversity: Continued improvement in our environment and commitment to EDI. Schools in this UoA hold current Athena Swan awards.
- Increased interdisciplinarity: New URIs, with Faculty re-structuring, have fostered interdisciplinary research efforts to help BN maximise opportunities for increased collaboration.
- Translational impact: Important growth since REF2014 in NIHR supported clinical postgraduate (7 academic clinical fellowships) and postdoctoral staff (6 academic clinical lectureships) is aligned with our focus to develop new areas of diagnostic and intervention research and improve clinical practice and health care.
- Contribution to society: UoA4 researchers pivoted to apply their expertise to COVID-19 facing research to produce an online vaccine handbook (**Lewandowsky)** and *SleepQuest* (**Coulthard, Piggins**) investigation (on medRxiv) of lockdown consequences on sleep, cognitive function, and circadian rhythms.

1b. Strategic and organisational advances since REF2014

The ethos of BN is scientific research excellence across the spectrum of the discipline. Our strategy is to grow disciplinary strength and breadth through strategic planning and networking across UoB and our two partnering NHS Trusts, whilst maintaining a strong focus on EDI. The schools and faculties that contribute to BN have undergone significant restructuring and re-positioning following REF2014, following a major strategic review of biomedical research at UoB to catalyse research excellence for REF2021 and beyond. This review triggered the coalescence of medical research into four key areas, BN (UoA4), alongside Cardiovascular Sciences (UoA1), Infection Immunity and Cancer (UoA1) and Population Health (UoA2).

To effectively oversee the renewal of Health and Life sciences, including BN, a new PVC Health and Life Sciences position was established (Iredale). The subsequent Faculty re-organization and enlargement (2017) of the Faculty of Health Sciences (FHS; Dean, Norman) hosting Bristol Medical School, and the creation (2018) of the Faculty of Life Sciences (FLS), which co-located PPN and PS in the same Faculty brought key research groups into closer alignment. A

reinvigorated and newly focused Bristol Neuroscience Health Research Network was formed (as an evolution of the Bristol Neuroscience community founded in 2003). This has promoted new shared purpose across school and faculty boundaries to increase interdigitation of research staff, maximize investment leverage, ensure effective and focused capacity building, and enhance the existing culture of interdisciplinarity to deliver excellence at scale.

BN is now led by Director of Neuroscience **Jones** (Wellcome Trust Senior Research Fellow) who oversees the strong framework of interdisciplinary collaborative research to ensure maximal integration and translation of knowledge and discovery into clinical applications. The refreshed BN research strategy is strengthened by links to local NHS Trusts, and heavily supported by the Elizabeth Blackwell Institute for Health Research (EBI, founded in 2012, received £3.75M in 2016 from Wellcome, matched by UoB). BN continues to build on these strengths with an impressive cadre of emerging PIs across the unit, and further collaborations with other University Research Institutes, the MRC-Integrative Epidemiology Unit (UoA2), the NIHR-Biomedical Research Centre (£21M), SPHERE (£15m EPSRC Sensor Platform for HEalthcare in a Residential Environment), and our GW4 partner institutions. The guiding principles of our research strategy are:

1. Investing in staff: We promote collegiate interdisciplinarity through dedicated support for the career development of all staff, especially ECRs, through engagement with the Concordat to Support the Career Development of Researchers (of which UoB was an early signatory). The institutional scheme enables this support of both post-doctoral researchers and externally-funded Bristol Clear independent research fellows. BN also has a strong EDI ethos in all aspects of our research culture (see 2a, 2b below)

2. Investing in students: We are committed to training the next generation of neuroscience PhD students, through the expansion and development of DTPs and the further development of the Bristol Doctoral College as a comprehensive resource for academic and pastoral support, as well as the availability of the same training opportunities as staff, as detailed in section 2b.

3. Investing in infrastructure and facilities: The large-scale re-structuring of FHS and creation of FLS brought together research and education in 7 schools, a centre for Health Sciences education and the Teaching and Learning for Health Professionals programme with a combined annual research income of ~£82M. This has provided UoA4 researchers access to superb research infrastructure (see 3c below).

4. Embedding RRI into our research environment: UoA4 champions this strategic theme, hosting the University-wide Academic Lead for Research Improvement (**Munafò**), and formally joining the UK Reproducibility Network (See 1f).

5. Disseminating and promoting research: Dissemination of research to academic and non-academic stakeholders alike is of central importance (see 4b). BN has a year-round programme of seminars with internal and external speakers, promoted in the weekly UoB-wide newsletter emailed to all staff; special bespoke academic and public engagement events, involving many enthusiastic UoA4 researchers.

1c. Activities and achievements of strategic research groupings

UoA4 has four research groupings: A. Memory and Cognition, B. Motor Control and Movement Disorders, C. Sensory Processing and Perception, and D. Cognitive Health and Wellbeing. We have broad expertise from basic and preclinical neuroscience, through computational neuroscience and psychology, to clinical neurosciences. PIs undertake significant cross-theme interactions, which will be realised by our move towards a 'hub' structure (see 1e).

A. Memory and Cognition (28 staff, 26 FTE)

Synaptic plasticity and memory:

- Core BN expertise is in quantifying the roles of distributed neural network activity in learning, memory, and decision-making. Building on our world-leading record of accomplishment in mechanisms of synaptic plasticity (e.g. original pharmacological characterization and function of the ionotropic glutamate receptor family), all PIs have translated their work into behaving rodents and, in some cases, humans.
- **Collingridge** (CBE, FRS, 2016 Brain Prize winner) employed genetic engineering, synaptic physiology and imaging to investigate the roles of kainate receptors in the hippocampus (ERC senior investigator award; Nat Neurosci, 2018).
- **Mellor** and **Ashby** have made breakthroughs in understanding of long-term potentiation and hippocampal synaptic plasticity (J Neurosci, 2018; Nature Comm. 2016), **Whitcomb** has investigated respecting synaptic adhesion molecules (Nat Neurosci, 2015).
- Circuit level understanding of hippocampal function has been furthered through Wellcome Investigator awards to **Warburton/Bashir** (£2M; PNAS, 2015; Cereb Cortex, 2016), **Jones** (£1.3M; Nature Neuroscience 2015) and **Mellor** (£1.1M; Nat Comms 2020), whilst **Anastasiades** (ECR and Marie Curie Fellow) is extending our knowledge of the role of cortical connectivity during development in neuropsychiatric disorders (Nat Comms, 2016).
- **Lewandowsky** employs computational modelling of memory and decision-making processes, concentrating recently on misinformation and climate change and COVID-19 vaccines (£900K Horizon 2020 funding to enhance vaccine uptake). He advised the Digital, Culture, Media and Sport Select Committee for Disinformation and 'fake news' in 2017 and 2018 and was funded by ESRC Impact Acceleration Award (IAA) to investigate cognition underlying climate change denial.
- Research by **Turk** and **Jarrold** investigating memory in both typical and atypical development in children (Cortex, 2020; J Exp Psychol, 2019) has led to the development of materials for educational psychologists through a UKRI-funded collaboration between local councils and UoB.
- **Mickes** has applied signal detection theory to memory in eye-witness testimony with National Institute of Justice (US) funding (PNAS, 2016).

Language:

There is longstanding and broad excellence in language research in BN, encompassing reading, spoken and written language production, speech comprehension, sentence processing, embodied cognition, computational modelling of language processes and cognitive neuroscience of language.

- **Bowers** (ERC senior investigator) studies how humans and artificial neural networks generalise across a range of domains, including memory and language (Psychol Rev. 2014).

- **Davis'** computational modelling work develops understanding of mechanisms underlying reading (Cognition, 2015).

Neurodegeneration:

- BN provides expertise and strategic leadership in translational clinical neuroscience and neurodegenerative disease research, from basic science to interventions. UoB has historical strength (>30 years) in brain banking through its charity-supported South West Dementia Brain Bank (SWDBB), **Love's** experience as co-Director of SWDBB and his research (NAN 2015; Brain 2016; Brain 2019) led to his appointment (2013-2020) as Director of the UK Brain Bank Network (UKBBN, funded by the MRC along with Alzheimer's Research UK, Alzheimer's Society, Autistica, Multiple Sclerosis, Society, Parkinson's UK, and BRACE), and hosting 11,000 brain donations. He oversaw transformative changes across whole of UKBBN to streamline brain banking operations to standards equalling, if not exceeding, those of US-based NIH-supported banks.
- SWDBB-supported research also advanced our understanding of mechanisms underlying Alzheimer's disease (Alzheimers Res & Ther, 2016) and Vascular dementia (Brain, 2015), some now deemed modifiable offering novel therapeutic options (Acta Neuropathol, 2020).
- **Kehoe**'s research on the renin angiotensin system in Alzheimer's disease (Alzheimers Res & Ther, 2016; Acta Neuropathol, 2020), has translated recently in the RADAR trial (ISRCTN93682878), a novel NIHR-EME funded Phase II study of the blood pressure drug losartan in Alzheimer's disease, and his invitation to serve as Co-Investigator in Emory University-led related trial in African-Americans (NCT02471833).
- **Ashby** identified critical changes in pre- and post-synaptic stability associated with reduced neuronal activity, that also occur in the pre-degenerative stages of an in vivo model of dementia (Cell Reports, 2017).
- **Scolding** is trialling interventions for multiple sclerosis (Lancet Neurol, 2017), informed by previous tissue studies.
- **Coulthard** investigates dopamine's role in long-term memory (e.g. DOPAMIND trial (ISRCTN90897054), reporting in early 2021), and reinforcement learning in Parkinson's disease (eLife 2017). A recent (£878K) MRC Momentum award links her work with the £15M EPSRC SPHERE monitored/instrumented house project.

B. Motor control, and movement disorders (10 staff, 10 FTE)

Movement disorders:

BN staff have been at the forefront of drug repurposing interventions and innovative neurosurgical methods to provide new treatments for movement disorders.

- Parkinson's disease (PD) and other movement disorders research led by **Whone** at the BMS-based Bristol Brain Centre was key to the multicentre VANTAGE trial to examine the effects of novel Deep Brain Stimulation device developed by Boston Scientific (see Impact Case Study [ICS]).
- HendersonE (UoA2) and **Whone** investigator-led trial (ResPOND, ISRCTN19880883) demonstrated how Rivastigmine improved a surrogate marker of gait stability in PD (Lancet Neurology, 2016). A new NIHR HTA funded (£2.1M) multi-centre trial (Chief PD ISRCTN41639809) is investigating Rivastigmine on falls in PD.
- **Whone** led a Parkinson's UK-funded ground-breaking and widely publicized (BBC2 and BBC Radio 4 documentaries) neurosurgical trial of convection enhanced delivery of glial cell derived neurotrophic factor (GDNF) in PD (Lancet Neurol, 2019). This work was enabled by

Bienemann's development of novel implantable catheter systems with Renishaw plc (see ICS).

- **Wilkins** identified novel uses of cytokine therapy for interventions (Ann Neurol, 2016) or cell transplantation approaches (Ann Neurol, 2018) for Friedreich's Ataxia, whilst testing the validity of biomarkers for future trials (EudraCT2017-003084-34). This intervention work has been extended by technology developed by **Uney's** group on the use of viral delivery techniques to investigate the validity of gene therapy (J. Biol. Chem. 2020), and transplantation of genetically modified haemopoietic stem cells as possible treatments for Friedreich's Ataxia role (MRC £664k, 2020).
- Pre-clinically, our pipeline is growing for intervention studies with **Cordero-Llana's** work (with **Uney** and **Wong**) on the potential of synergistic approaches for PD treatment, including ground-breaking findings of therapeutic benefit from combined neurotrophic factor delivery in Preclinical Models of PD (Mol Ther, 2015); and in the regulation of brain alpha-synuclein levels (Mol Ther, 2017).

Motor Control:
PPN neuroscience research uses whole animal *in vivo* (systems) approaches to understand the control of movements by supraspinal neural networks.

- **Chadderton** (Wellcome Trust Investigator Award 2018-2023) showed that movement trajectories can be decoded from single cerebellar neurons (Nature Comms, 2017), leading to the development of methods to robotically target neurons for patch clamp recording and assay synaptic connections at the subcellular level (Cell Reports, 2018).
- **Apps'** research has defined how the cerebellum interacts with other brain regions involved in motor adaptation, cognition and emotional behaviour (J Physiology, 2014).
- Through work investigating how basal ganglia neurons encode motivated behaviour, movement and effort, **Dodson** has identified how spontaneous movement is differentially encoded by distinct types of neurons and how this is perturbed in models of PD (PNAS, 2016).
- **Leonards** and **Ludwig** direct the Wellcome Trust-funded Bristol Vision Institute Movement Laboratory within PS, which houses a 10-camera motion capture system allowing **Leonards** to discover important influences of the visual environment on gait (Roy. Soc. Open Sci, 2015).

C. Sensory processing and perception (10 staff, 9.4 FTE)

Sensory neuroscience:
Understanding how wide-ranging peripheral sensory inputs modulate, and are modulated by, ongoing activity in the brain galvanises a long-standing research effort within the Sensory-Motor Systems Group to understand how sensory experience is represented in the brain and spinal cord.

- **Lumb** and **Apps** have investigated descending sensory modulatory systems that originate within the brain and regulate spinopetal transmission of sensory information which underlies the transition from acute to chronic pain (J Neurosci, 2016).
- **Pickering** and **Gill** utilise clinical and preclinical studies to investigate the neuromodulation of sensory-related activity in the peripheral and central nervous systems associated with pain, anaesthesia and autonomic control (eLife, 2017; Resuscitation, 2014). This is complemented by important research on nociception, involving galanin by **Wynick** (Mol Cell Neurosci, 2017).

- **Ashby** described the encoding of sensory experience in the primary sensory cortex (Nature Comms, 2016), and sensory representations triggered by brain maturation and neurodegeneration (Cell Reports, 2017).

Visual perception:
Our strength in visual perception research is evidenced by continued strength of the Bristol Vision Institute (BVI), which has been successfully stimulating research interaction and collaboration in science, engineering, arts and medicine since its creation in 2008 with the aim of addressing grand challenges in vision research.

- **Gilchrist & Ludwig** co-lead a BVI hosted £1.4M 'Vision for the Future' EPSRC platform grant, aiming to develop a deeper understanding of the fundamental aspects of perception and visual processing in humans and animals (with UoA5 colleagues), across the domains of immersion, movement and visual search, coupled with innovative engineering solutions (led in UoA12). A linked EPSRC IAA award supplemented this platform grant ('Media Immersion Measurement Service')
- BVI also underpinned the £30M 'MyWorld' award to UoB from the UKRI's Strength in Places Fund, with a further £16m coming from industry and academic partners for a five-year scheme to support the regional creative industries. **Gilchrist** leads one of the four core programmes focused on audience responses.
- **Ludwig** has made important advances in perceptual decision making and saccadic eye movements (PNAS, 2014).
- The camouflage group (**Baddeley, Scott-Samuel**) work closely with colleagues in UoA5 to study signal processing, optics and mechanisms of perception in both natural (PNAS, 2018, 2020) and applied contexts (PLoS, 2016). The group has raised over £2M in the review period from UKRI, government (DTSL) and industry (Qinetic) sources.

D. Cognitive Health & Wellbeing (35 staff, 31.94 FTE)

Neonatology:
UoB has an important legacy in pre-clinical discoveries of mechanisms of neurological damage in neonatology and innovative solutions that have led to clinical interventions.

- **Thoreson** & **Chakkarapani** continue their leading work into the therapeutic benefits of neonatal cooling (see ICS), conducting the CoolXenon trial, which recruited 450 newborns who have received cooling therapy since 2007. This cohort shows that cooling reduces epilepsy (Epilepsia, 2017) and severity of cerebral palsy (Arch Dis Child Fetal Neonatal Ed, 2020).
- **Luyt** led the NIHR-funded DRIFT trial, a study of structural and functional brain development in school aged children after severe intraventricular haemorrhage and ventricular irrigation therapy. Cognitive status was significantly better in children who received DRIFT vs. standard treatment (HTA, 2019). **Luyt** also heads the NHS-funded National Child Mortality Database (est. 2018).
- **Luyt** has extended her work to prevent cerebral palsy associated with pre-term labour, that arose from the PReCePT1 care quality improvement package. PReCePT1 informed 2016 guidelines regarding use of magnesium sulphate in all women with pre-term (<30 weeks) labour to protect baby brains (see ICS). **Luyt** now leads the nationally important PReCePT cluster randomised trial (ISRCTN40938673), to evaluate the impact of enhanced implementation of the National PReCePT programme to reduce adverse outcomes in neonates.

Neurovascular and Neuroglial Neuroscience:
Multidisciplinary approaches (from cultured cells to whole animal, to human) investigate how central networks control autonomic functions and how lesser appreciated non-neuronal parts of the brain, the glia cells, contribute to brain function.

- **Abdala** collaborates with industry to gain insight into molecular mechanisms of brain deficiencies in Rett syndrome (J Physiol. 2015), intended to develop new therapies for this syndrome. Her research is closely linked to both industry through collaboration with Neurolixis, and through her work as scientific advisor to Rett UK.
- **Kasparov** studies brainstem control of hypertension and has discovered novel signalling mechanisms that control release of important neuromodulator noradrenaline (Nat. Commun. 2014).
- **Miners** has shown that abnormal vascular contractility contributes to pathological hypoperfusion in dementia (Brain, 2015).

Stress and Endocrinology:
BN leads major research into the hypothalamo-pituitary-adrenal axis and how this responds to stress, exercise and altered time cues.

- MRC-funded translation work led by **Lightman** (FRS) has shown the importance of human cortisol dynamics (JCEM, 2019; Critical Care Medicine, 2015).
- **Reul's** Neuro-Epigenetics Group researches the impact of stressful events on the brain and how epigenetic, signalling and gene transcriptional changes in the rat hippocampus influence stress responses (PNAS 2016).
- **Murphy's** group investigates the transcriptomic responses to osmotic and cardiovascular stimuli (J. Neuroscience 2014; Nanotoxicology 2017).

Mental Health and Health Behaviours:
Mental Health and health behaviour research in BN spans animal models to internet delivered interventions. An interdisciplinary Mental Health Strategy group (formed 2018) chaired by **Haworth**, oversees Mental Health Research at UoB, responds to research priorities, and supports applications to funders.

- **Robinson** has developed novel animal models of psychiatric conditions with major industrial (Boerhinger Ingelheim) and research council funding to determine anti-depressant mechanisms, including studying ketamine as an acute treatment for depression (Neuropsychopharmacology, 2017).
- The Tobacco and Alcohol Research Group (**Munafò** [Clarivate 'highly cited' researcher since 2018]**, Attwood, Maynard (ECR)**), researches the psychological and biological factors underlying health behaviours and is part of the MRC Integrative Epidemiology Unit (see UoA2). They have shown smoking cannabis is a causal risk factor for schizophrenia (Psychol Med, 2016), and that early cannabis use is associated with higher rates of nicotine dependence, harmful alcohol use, and illicit drug use (J Epidemiol Community Health, 2017). Further work investigates e-cigarettes and youth smoking behaviours (Tob Control, 2020). **Maynard (ECR)** continues to investigate the effects standardised packaging on cigarette use (ICS).
- **Penton-Voak** and **Munafò** are co-investigators on the NIHR Bristol Biomedical Research Centre (BRC) Mental Health Theme (circa £2.4M), investigating causal pathways between cognition and mental health disorders in epidemiological datasets and developing digital health interventions (Psych Med, 2019), in collaboration with industry with Innovate UK and

MRC Experimental Medicine Challenge Grant funding. Related work supported by an EPSRC IAA and an MRC Confidence-in-Concept award (**Attwood)** is developing a classroom based digital intervention for children with ASD.

- **Haworth** leads the Mental Health Data Science Group (working with colleagues in UoA2), linking social media data to cohort studies for mental health research (Nat Gen, 2016), and was awarded a Philip Leverhulme Prize in 2018.
- The Nutrition and Behaviour Unit (NBU) **Brunstrom**, **Rogers** and **Ferriday** have been awarded £2.1M (BBSRC and EU) to study food choice, energy intake, and dietary influences on mood and cognition (J Nutrition, 2019; Appetite, 2015; Int J Obesity, 2015). The NBU work closely with industrial partners to develop tools to assess satiety (see ICS). **Rogers** leads the type 2 diabetes workstream in the Nutrition theme of the NIHR BRC.

Sleep:
Sleep and circadian rhythms are an emerging area of research and a future priority of BN.

- **Piggins's** BBSRC-funded research investigates the neural basis of circadian rhythms (J Neuro 2014; J Physiol 2014) and the long-term effects of exercise on circadian function and ageing.
- **Hodge** investigates circadian rhythms in invertebrate models of neurodegenerative disorders and ageing (Neurobiol. Dis. 2019), while **Rolinski** (ECR) investigates REM sleep behaviour disorder in prodromal Parkinson's disease as a patient risk stratification tool (Sleep, 2017).
- **DeVivo** and **Bellesi** have reported how synapse structure changes across sleep state (Science, 2017).
- **Jones** is leading new translational approaches to the study sleep and cognitive disturbance in larger animals (Brain, 2015) and in psychiatric disorders (Psychological Medicine, 2020).

1d. Future strategic plans.

Following the appointment of **Jones** as Director of BN and the accompanying strategy refresh, BN's priorities and direction are nucleating around five interwoven neuroscientific 'hubs' (figure 1). These hubs – **Memory (**led by **Mellor), Movement (Chadderton), Mental Health (Haworth)**, **Neural Computation** (Conor Houghton, Computer Science) and **Sleep (Jones)** – allow the co-localisation of interdisciplinary expertise to research the fundamental questions of brain function in health and disease and build on the strategic research groupings outlined above. The depth and breadth of these themes reflect BN's mission to deliver on our strategic investments to date. The hubs recognise and exploit existing and potential research interfaces to deliver 'Brain research for better lives' over the coming 5-10 years. Each hub is led by a Strategic Oversight Group convening fundamental, clinical, computational, psychological, and epidemiological expertise, with ECR, PGR and undergraduate representation. Hubs integrate across organisational nodes of BN and are already expanding to embrace new research and methodologies (and possible new hubs) across disciplines including the Bristol Veterinary School, Biological Sciences, Engineering Maths, Computer Science, the Bristol Brain Centre and the NHS; the breadth of which sits comfortably within BN's unique capability and will ensure effective translation of impactful research that benefits the public, patients, doctors and industrialists. BN's hubs will provide clear collaborative portals for the various internal research-facing entities including the EBI, MRC Integrative Epidemiology Unit (IEU), NIHR BRC, Digital Health, plus academic (e.g. GW4) and industrial partners. The recent appointment of Golam Khandaker (early life risk factors, neurodevelopment and adult psychosis) strengthens links with the MRC Integrative Epidemiology Unit. Individual hubs are intended to

evolve into externally-funded 'Centres', undertaking the best neuroscience research in the thematic priorities. The complementary foci of BN's four current hubs are bound by two new cross-cutting themes:

1. Neural algorithms: the synaptic, cellular and circuit mechanisms of neural information processing
2. Lifelong brain health: neurobiologically informed approaches to nurturing and treating individual and population variation in brain health

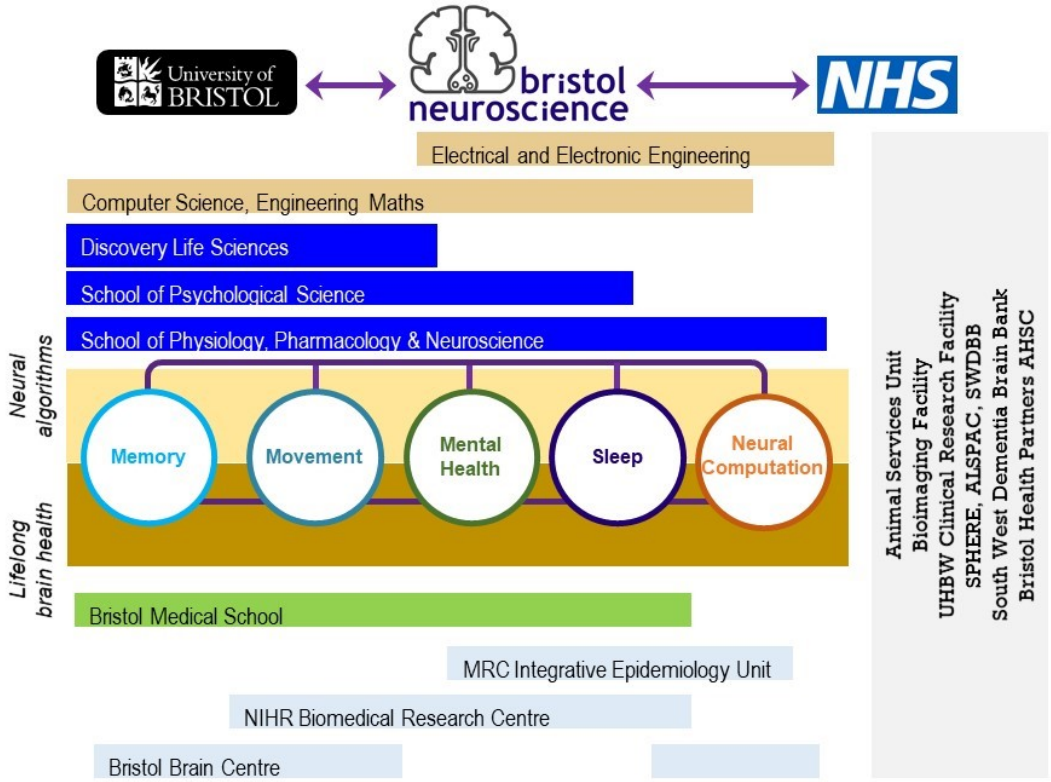

Figure 1: BN's new hub structure, indicating contributing schools (three in this UoA), cross-cutting themes, and infrastructure underlying research.

1e. Impact strategy

Our Wellcome Trust supported central Translational Research Hub (TRH), within our Research and Enterprise Division (RED) acts as a single-entry point for the translation of health and life sciences research. The TRH Steering Group is chaired by the PVC Health, Iredale, and includes our UoB-funded Entrepreneur-in-Residence, Richard Seabrook (formerly Wellcome Trust Head of Business Development). The TRH has increased from 2 to 8 FTE during the current REF period, and 'hides the wiring' to simplify partnerships with key stakeholders, whilst providing an accessible single-point-of-contact into UoB for companies seeking to explore commercialisation and collaborative opportunities with us. The TRH has overseen the strategic deployment of £3.9M of devolved portfolio funding received since 2014 (i.e. MRC Confidence-in-Concept (£2.2M) & Proximity-to-Discovery (£600K), Wellcome Trust iTP (£800K) Awards and BBSRC IAA and Flexible Talent Mobility Award (FTMA)).

This devolved portfolio funding enabled UoA4 staff to increase impact and undertake visits and secondments to Industry. BBSRC FTMAs have allowed placements to explore analysis of laser evoked potentials to establish a translational biomarker of pain processing with Eli Lilly and deliver

functional neuroanatomical mapping following cerebellar stimulation with Takeda. Staff time for translational work is protected via allowances in workload models and impact sabbaticals. Additional training opportunities are available through the UoB Centre for Innovation and Entrepreneurship. Our Faculty restructuring and BN hubs are designed to facilitate staff in meaningfully translating their research to maximise societal impact and benefit.

Each school has a dedicated Academic Impact Lead who pro-actively identifies ongoing research with potential impact, and then to works with the RED Knowledge Exchange (KE) team to realise commercialisation potential. This includes partnership development, identification of funding sources (e.g., KTPs, and EBI-funded, RED-supported projects to increase success rates) and advice on impact delivery. PS has an external advisory board, chaired by Steve Gatfield (group chairman of Elmwood Design), consisting of representatives from industry, psychology, and charity sectors to promote engagement with non-academic partners.

1f. Research integrity

BN is committed to supporting a strong research environment underpinned by a culture of integrity, excellence and continual improvement. UoB has acted as advisor to the UK Research Integrity Office and is a committed and early adopter of the principles of the Concordat to Support Research Integrity, with clear policies and procedures that all staff are expected to follow. UoA4 staff, are at the forefront of recent advances in research integrity and reproducibility, evidenced by influential metascience publications in our submitted outputs (e.g. **Atwood, Munafò** and **Penton-Voak** were co-authors of the Open Science Collaboration's 'Estimating the Reproducibility of Psychological Science' (Science, 2015) that has amassed 2650+ citations), and the profile of senior researchers in the area (**Lewandowsky** gave evidence to UK Parliament, Science and Technology Committee, Research Integrity Inquiry, 2017). UoA4 also champions UoB's lead in the UK Reproducibility Network (UKRN), of which is **Munafò** is co-founder and co-leads. Internally, **Munafò** is the University-wide Academic Lead for Research Improvement and Integrity reporting directly to the PVC for Research and Enterprise (Taylor, UoA12), and working to enhance a positive culture of research integrity and improvement across UoA4 and the wider institution, by:

- Ensuring integrated training and development programmes for researchers at all stages of their research career.
- Ensuring dedicated academic and research professional support and mentoring at all career stages, including support for UKRN Local Networks.
- Assessing issues that lead to academic staff feeling pressured into taking "short cuts" and exploring wider improvements in research culture.
- Supporting national policy framework development, including working closely with UKRN.

Research improvement (including research integrity and research culture) is embedded within all doctoral training programmes, and a modular series of short courses on topics ranging from data skills to leadership is in development. Informally, there are several postgraduate-led initiatives (e.g. ReproducibiliTea journal clubs). Building on UoB's leadership in UKRN, a major philanthropic investment (£1.6M) from industrialist John Climax will enable improvements in the robustness and speed of translation of BN research.

UoB policy is to make all scientific outputs open access through deposition of manuscripts on our PURE repository system. In UoA4, we have >85% compliance with this and increased take up will be encouraged through new mandatory training modules on Open Access obligations as part of

the introduction of new online annual review portal. Compliance is managed at school level via monthly reports. A central repository for pre-prints and supplementary data is available, supported by a long-term research data storage facility (RDSF) to ensure retention of key data and persistent identification through assignment of British Library DataCite Digital Object Identifiers.

2. People

2a. Staffing strategy and staff development

Our staffing strategy is to appoint, support and develop the very best individuals whose research interests enhance our existing research themes, or enable and underpin new strategic directions. We maintain a strong focus on EDI. Our goal is to make UoB a continually supportive and collaborative environment for established PIs, as well as a desirable training destination for ECRs (postgraduate and postdoctoral) where career progression is seen to be supported and valued, building a BN that becomes internationally recognised as a launch pad for future leaders. BN strives for success from teamwork, collaboration and collective excitement and celebration, rather than encouraging ruthless competition, all directed with the ambition of conducting the best neuroscience research, undertaken by the best neuroscientists.

New external appointments since REF2014:

- Two Professorial appointments: **Piggins** strengthens our new BN sleep hub and leads PPN, and **Mickes,** whose applied eyewitness work further bolsters our existing strengths in memory.
- Seven Lecturer/Senior Lecturer appointments (L/SL/Associate Professors): **Anastasiades** (ECR) and **Quadflieg** in Cognition and Memory, **Ferriday** (ECR), **Haworth**, and **Maynard** (ECR) in Brain Health and Wellbeing, and **Chadderton** and **Dodson** in Movement and Motor Control.
- As part of UoB's continuing commitment to neuroscience, we have interviewed for 3 new academic positions in neuroscience in 2021.
- We attract excellent non-clinical ECRs through substantive externally-funded post-doctoral fellowships. Recent awardees include **Miners** (2019), Alzheimer's Research UK Senior Research Fellowship (£420K); **Maynard** (ECR), a recipient (2017) of an ESRC future leader fellowship and a ESRC New Investigator award. **Anastasiades** (ECR) secured (2020) a Marie Curie Fellowship. **Skinner** was awarded a UKRI innovation fellowship to work in digital health. We have also supported internal fellows from BN funds (**Bellesi** and **de Vivo**) whom have since (2020) secured lectureships at leading Italian universities. **Domanski** and **Skatova** (ECR) are Turing Institute Fellows and **DasGupta** is a recent recipient of a Wellcome Trust Sir Henry Dale Fellowship. Since REF2014 we have worked to increase our capacity to similarly attract clinical ECRs (see below).
- Success in attracting external fellowships is underpinned by a recent novel in-house funding scheme, the "Vice Chancellors Fellowships" (VCF). Overall, UoB has appointed 41 VCFs at an average cost of £0.2M each. In UoA4 VCFs supported **Dasgupta** (through a generous alumnus donation from the de Pass family), and **Skatova** before their external awards. A further VCF was awarded to Williams (then in PS, who went on to a Lecturer in Marketing post at UoB).

Internal promotions via an EDI-directed procedure are a key means of recognising staff achievement in research, teaching and collegiality which has greatly benefitted our gender balance.

- Six UoA4 members have been promoted to Professor: **Haworth, Leonards, Luyt, Robinson, Warburton** and **Scott-Samuel**.
- Four others have been appointed to Associate Professor: **Attwood, Coulthard, Wong, and Hodge.**

Staff development: Staff are supported through mentoring (including Bristol Clear) and staff development workshops and courses (including training in leadership, teaching and management) and through annual staff review and development appraisals.

- *Workload models* provide transparency in balancing teaching, research, administration, translational and wider academic contributions. Newly appointed staff have reduced teaching and administration loads to facilitate establishing successful research programmes. For clinical staff, consideration is given to shared NHS and UoB job plans, which are reviewed and approved by Department or School Heads annually.
- *Senior staff mentor new staff*, especially research fellows. In UoA5, an external mentor scheme was trialled in 2015 for all academic staff (PDRAs included). Mentors are ex-UoB staff who host in-house sessions with academic staff and postgraduates and provide career and well-being support (reporting to EDI Committee). This led to clear improvements from in 2014 where only 60% of men and 38% of women felt they received effective career support. In 2017 this had risen to 70% of men and 63% of women (Staff Satisfaction Survey). This scheme is now used across the Faculty of Life Sciences that hosts PPN and PS staff. A similar mentorship scheme was piloted in BMS in 2019 and undertaken again in 2020 and will be part of ongoing EDI-supported changes to supporting staff in BMS.
- *All new lecturers join the CREATE scheme*, allowing participants to become Fellows of Advance HE. For female members of staff, there are now additional specific leadership schemes: the Female Leadership initiative (Fli) and AURORA.
- The University Research Fellowship (URF) scheme allows applicants teaching relief to pursue new research projects. Five UoA4 staff have held URFs since 2014.

Tailored support for early career postdoctoral researchers: Postdoctoral Research Associates (PDRAs) are a large proportion of our workforce (~65%), and central to our research success. UoB operates an inclusive policy to improve job security for those employed on fixed term contracts, ensuring they are named researchers or Researcher Co-Investigators on grant applications where appropriate, and these staff have priority for upcoming vacancies through redeployment processes prior to recruitment going externally.

- *PDRAs have access to extensive training opportunities* and are treated identically to core-funded staff in terms of annual staff review and training. Much of this is supported via Bristol Clear (see Ref5a), an institution-wide body created in 2018 to provide mentoring, guidance on research careers and links to services and opportunities across UoB (e.g. Staff Development Services) and externally.
- BN's PDRAs run a 'Circuit Neuroscience Seminars' series, hosting international peers, notably those transitioning to independence.
- The *UK Concordat to Support the Career Development of Researchers* has been adopted by UoB (one of the first institutions to do so) and our employment practices and policies

operate in line with its principles. UoB has held a European Commission Human Resources Excellence in Research Award since 2010 (renewed in 2019).

- PDRAs and ECRs participate on new BN hub steering groups, thereby shaping and running workshops and organising the annual BN research symposium.
- Bespoke training for ECRs in Responsible Research and Innovation has been prepared, tested and launched via the Horizon 2020 PERFORM project (a three-year research project (2015-2018), centred on Paris, Barcelona and Bristol) using performing arts techniques to inspire and motivate young people to develop a more reflective and holistic understanding of science.
- Career development is further supported through *ongoing availability of successive postdoctoral fellowships* including bridging fund opportunities, where required, from EBI and School funds. CV review has been added to the staff annual review process, encouraging staff to reflect on their trajectories for career advancement, identify areas for improvement and development opportunities with their line managers to facilitate and increase competitiveness for progression, promotion or for future employment.

Tailored support and pathways for clinical Early Career Researchers: Alongside the mentored training track for both basic and cognitive neuroscientists, we have parallel clinical-facing schemes including our clinical academic training track, and bespoke EBI-funded clinical primers to attract talented post-graduate medics, dentists and veterinary professionals to re-enter research. These opportunities nurture our scientific and clinical scientific staff, increase their competitiveness towards subsequent PhD and fellowship funding, and develop future leaders.

- An important early career pathway is provided by the Integrated Clinical Academic Training (CAT) Pathway (Bristol ICAT). This provides a supported and mentored clinical academic training programme for Medics, Dentists and Vets and aligns a series of complimentary training components to develop future clinician scientists from studentships through predoctoral work (INSPIRE research awards, EBI clinical primer grants, Academic Clinical Fellowships), doctoral studies (£5.1M Wellcome Trust supported GW4-CAT PhD programme) and postdoctoral studies via clinical lectureships to provide “cradle to consultant” training. Since 2017, 4 of the 12 GW4-CAT appointments have been in BN.
- Since 2014, a strong pipeline for clinical neuroscience research capacity has grown evidenced by the appointment of 7 NIHR-funded Academic Clinical Fellows (ACFs), and 6 NIHR Academic Clinical Lecturers (including **Rolinski** (ECR)), where the majority (n=4) are based at the Brain Centre and working on dementia neurology (the remainder were Southmead Hospital-based Neurosurgeons). This growth in clinician training in Neuroscience is further supported by additional Academic Foundation Programme (AFP) candidates annually, each getting 4 months of research time. Through effective prospective management of doctoral candidates and NIHR and UoB support, successful PhD fellows graduate to lectureships to continue mentored post-doctoral development and support in the pursuit of more senior fellowships with major funders. The success of this mentored support approach is evidenced by recent externally-funded success in BN: 1 MRC Senior Clinical Fellowship, 2 Wellcome Trust-funded PhDs and 1 Alzheimer’s Society Junior Fellowship. This clinical academic cohort is supported through a combination of the NIHR ACF/ACL and GW4CAT schemes led and coordinated by Professor Debbie Sharp OBE (UoA2) and PVC Iredale (UoA1). Further support is provided by a UoB-funded administrators and BMS Postgraduate and Research Directorate **Kehoe.**

2b Doctoral training

UoA4 hosts a vibrant community of doctoral and masters-level research students and has awarded 255 PhDs since REF2014. UoB's success in open competitions for doctoral training programmes (DTPs), particularly those offering interdisciplinary training opportunities as both a single institute and partner in GW4, offers an outstanding doctoral training environment.

Cohort structure and training programmes:
The postgraduate student body typically contains about 100 PhD and 10 MRes students (>60% female, >15% BAME). There is a strong focus on diversifying the research student cohort, with specific policies being actioned by the BBSRC SWBio DTP and Wellcome Trust.

- PGR student administration is managed through the FLS and FHS Graduate Schools, which in turn are integrated within the Bristol Doctoral College (BDC). The BDC organises UoB's Personal and Professional Development programme for postgraduate research students, complementing programme-specific and Faculty level training that was commended by the Quality Assurance Agency in the 2016 Higher Education Review of UoB.
- In 2018, UoB launched a new centrally located Postgraduate Researcher Hub operated by BDC. This centre is dedicated to supporting the personal and professional development of postgraduate researchers alongside the promotion of their health and wellbeing in partnership with both internal and external support services, such as the UoB Wellbeing Service and Bristol NHS Wellbeing Therapies.
- Many PGR students within BN belong to *Doctoral Training Programmes* that provide structured research training, particularly in Year 1. The Wellcome Trust Neural Dynamics DTP, is a flagship programme led by **Apps**. The first cohort completed in October 2015, and all graduating students secured postdoctoral positions in prestigious international research groups or in industry. These students have catalysed new collaborations and novel avenues of research combining the latest neuroscience methods and computational approaches and developing the two-way interaction between our understanding of brain and of machine intelligence. Workshops on gender and assertiveness, regular wellbeing tutorials, and an international student exchange programme with Bordeaux Neuroscience have all been other outcomes. The Wellcome Trust also funds the GW4-CATscheme (lead **Iredale**, £5M, see section 2a), and the Dynamic Molecular Cell DTP (5 BN students in this REF period). On average 9 students in our cohort are funded by the Wellcome Trust.
- Cohort students benefit from a wide range of DTP hosted activities e.g. annual student conferences, scientific industrial site visits, thematic-based seminars, three-month internships and student-arranged away days, and career development activities. The strong cohort identity developed in these programmes provides valuable and much appreciated peer support for students throughout their doctoral training. Other local and GW4 programmes that fund UoA4 students include:
    - BBSRC SWBio DTP. This SW cross-institutional partnership lead by UoB (~£30M), has ~130 PGRs across the partnership with ~50 based at UoB, 11 funded in UoA4.
    - ESRC South West Doctoral Training Centre (SWDTC) provides postgraduate research training in the social sciences and psychology across Bristol, Exeter and Bath and has been allocated 41 ESRC 1+3 studentships annually (8 UoA4 studentships in review period).

    - MRC GW4 biomed DTP (£4M; 18 studentships annually). The MRC IEU has also supported 5 UoA4 relevant studentships across the period, with 10 students on average funded by the MRC in any given year.
    - EPSRC DTP COMPASS, which provides training statistical and computational techniques of data science, and the recently awarded EPSRC DTP in Digital Health and Care, with an intake of 10 students annually who can work within UoA4.
- Studentships are also supported or partially supported (e.g., CASE funding) through industrial collaborations (e.g., with Qinetiq, Eli Lilly, Hello Bio, NeuroSolutions, Compass, and Cambridge Cognition).
- Additional students are funded by charities (e.g., BHF, Leverhulme, Alzheimer's Society), and, internationally, the European Research Council, foreign governments (e.g., Malaysian Government, China Scholarship Scheme) and overseas research agencies.
- *UoB postgraduate scholarships* enable us to attract the very best UK and overseas students in addition to Dean's Scholarships and the China Scholarship schemes.
- We also host 10-15 Masters by Research students annually, many of whom stay for doctoral study.

Supervisory structure:

- All PhD students have at least two supervisors, with some second supervisors from outside their School (often from UoAs 1 & 2 for health-based students, or UoA11 for neural dynamics PhDs), which encourages good practice, collaboration, and interdisciplinarity.
- They also have an annual review with a separate advisory panel to review progression decisions.
- Student well-being and diversity are of paramount importance to us, and students have access to multiple forms of support: supervisors/advisory panel, School Graduate and Personal Tutors, a team of 11 Faculty-based Wellbeing advisers, and the Student Support Service providing access to counselling, GPs/medical and disability advisers. The informal support of the DTPs along with the strong cohort-based sense of community are also notable, as is the scope where needed for part-time study, medical suspensions and extensions, as enshrined in UoB student and study regulations.
- Students nearing the end of their training are eligible for BBSRC FTMA financial support (UoB awarded £251K to scale up existing relationships or develop collaborative projects with academic or industrial partners).
- PhD students get the same career development and training opportunities available to ECRs. A specifically tailored module in our CREATE programme enables PGRs to gain insight into academic careers while gaining a postgraduate certificate in teaching in Higher Education. The Careers Service and the BDC work closely to support PGR student career-readiness e.g., the promotion of the Bristol-Plus award for PGR students to enhance employability skills.

2c Equality and Diversity

UoB is strongly committed to support equity, diversity and inclusion (EDI) and aspires to become a sector leader in the delivery of this key priority. UoB's EDI governance structure was recently overhauled to better monitor, evaluate and share activity and progress. Our institutional champion for EDI is the DVC & Provost, whilst the PVC for Student Experience provides specific leadership on student inclusion. Both are part of the EDI oversight group and Inclusion Forum, where good practice is shared, achievements celebrated, and common challenges addressed (see REF 5a).

- All Schools in this UoA hold either Silver (BMS) or Bronze (PS, PPN) Athena Swan awards.
- Diversity data are routinely collected and regularly analysed on our staff and student populations to inform activity to better attract, retain and develop groups that are currently under-represented. Progress is monitored against Strategic Performance Indicators outlined in REF5a. BN has actively sought to address EDI issues by facilitating the promotion of five female staff to Professor, and appointing one external female Professor, as well as promoting three female Senior Lecturers to Associate Professor. We have increased UoA4 female staff from 23% in 2014 to 31% in 2021.
- UoA4 has several school-based designated EDI champions. School/Faculty SWAN/EDI committees maintain well-developed and informative web pages and take an anticipatory approach to enable and support a culture of equity and collegiality. This ensures that policies and practices (including maternity/paternity, adoption, and care leave) are met. Schools are committed to decolonising the curriculum and to increasing the visibility and leadership opportunities of BAME staff and students across all media, with online courses available to staff.
- **Kehoe** (BMS Research Director) sits on a research and outcomes special interest group, involving a mix of both White and BAME staff and students in the newly formed BMS Medical Anti-Racism Taskforce (MART). BMS MART is tasked with monitoring wellbeing and representation of under-represented staff, addressing staff training and BAME attainment gaps to inform workforce planning.
- Our *Appropriate Behaviours Policy* provides pro-active routes for dealing with harassment, bullying and other inappropriate behaviours, and includes access to both a 'Report + Support' tool and an in-house mediation service. Awareness of this support was raised with a recent 'Stand Up and Speak Out' initiative.
- 11 School Mental Health Champions have been appointed to recognise these important challenges. Mental health support has increased with the establishment of UoB policies for staff and students, and substantial UoB investment in in-house counselling and health services (additional £1.5M from 2018, and 30FTE employed in a student-support well-being service).
- Our diverse international PGR community is supported pastorally by the International Office, helping students make a successful transition to UK higher education, whilst similar support exists for staff with concerns or issues following EU exit.
- BN PGR students recently established the Inclusive Research Collective, an initiative to educate UoB staff and students on non-inclusive research practices and to challenge biased methodologies within biomedical and healthcare research.
- Progress on EDI is measured through our involvement with a range of external accreditation schemes that recognise best practice in EDI such as the Athena SWAN Charter, Race Equality Charter, Stonewall Diversity Champions programme, and the Disability Confident Scheme.

3. Income, infrastructure and facilities

3a. Research funding

In awards metrics (2018/2019) amongst UK Universities UoB ranked 5th for BBSRC funding, 10th nationally for MRC funding, and 6th for Wellcome Trust funding and had the top success rate for competitive UKRI awards in the Russell Group (38% award rate by number).

The unit has an external research grant spend of ~£63 million over the period of assessment as detailed in REF4b. Total annual grant spend has been maintained at £8-10m. Our income is derived from diverse sources, primarily competitive, including UKRI, NIHR, major charities and industrial partners. In addition to the extensive support gained through early career awards (detailed below), major sponsors are the MRC, BBSRC, Wellcome Trust, H2020, and ERC. The breakdown of these grants is 49% UK Research Councils, 30% UK charities, 9% UK Government and Industry, 8% EU and 2% Overseas.

Individual awards are highlighted throughout this statement, but key funding include awards from the Wellcome Trust (Joint Senior Investigators, **Warburton/Bashir (**£2M); Investigator, **Mellor** (£1.1M) and **Chadderton** (£1.5M), Senior Fellowship, **Jones** (£1.3M)), and ERC senior investigator awards to **Collingridge** (£2M) and **Bowers** (£1.8M). **Lightman's (**£1.8M, MRC**)**, and **Murphy (**£1.1M), Mellor (£875k), all BBSRC.

Considerable income is not captured in these figures, where grants are administered through other UoAs. These are numerous and include:

- £23M NIHR BRC (**Brunstrom, Rogers, Munafò & Penton-Voak** co-Is).
- UoA4 involvement (**Gilchrist, Ludwig)** in the MyWorld (£30M investment from UKRI), and the BVI EPSRC platform grant (£1.4M).
- **Whone's** involvement in the NIHR HTA Chief-PD trial (£2.1M).
- **Jones'** contribution to a Wellcome Strategic Award led by Cardiff (DEFINE - Defining Endophenotypes from Integrated Neurosciences, £6M, 2013-19).

3b. Facilities and organisational infrastructure supporting research and impact

Research and Enterprise Development (RED, see REF5a)**,** overseen by the PVC for Research and Enterprise (Canagarajah to 2019, now Taylor), is a central UoB division with 80+ specialist staff, who work with academics on multiple levels to help sustain and grow research activity**.** This complements Iredale's PVC leadership of Health and Life Sciences, and includes identifying funding opportunities, supporting the development and sponsorship of research proposals, coordinating large, collaborative or complex bids, negotiating research and consultancy contracts, strategic project management, and improving the impact and commercialisation of research by working with business. RED also ensures the delivery of robust research governance policies (and training where appropriate) across UoB for a range of research activities, including research ethics, infrastructure; data storage and management; appropriate use of animals and human tissue in research; grant management and other regulatory issues.

UoB supports our research with impressive institutional facilities and infrastructure developments, notably:

UoB Animal Services Unit (ASU): In vivo facilities include a barriered breeding facility (~1000m^2) holding ~120 lines of genetically altered mice; and multi-use research facilities totalling ~2000m^2. Neuroscientists represent ~50% of the users of ASU, which include animal holding space, surgical procedure rooms and behaviour rooms that allow long term electrophysiological recording studies in rodents. Dedicated procedure rooms are available for the use of viral vectors up to Category II and a 2-photon microscope (**Ashby)** for in vivo live imaging research. Total direct spend for the unit is £2M per year (~50:50 consumables and staffing) with total UoB staffing levels in 2020 of

28.5 FTE plus agency staff and attributed costs of ~£5M annually. £1M was invested in ASU during the COVID-19 pandemic to upgrade service provision.

Bristol Translational Biomedical Research Centre (TBRC): This £6.3M (UoB, MRC, BHF co-funded) national facility for large animal research (opened 2016), is located on our Home Office-approved animal maintenance facilities at the Bristol Veterinary School, Langford campus. It includes a research hospital, operating to NHS standards, with induction room, surgical facilities and post-operative critical care, and is complemented by state-of-the-art imaging (3T MRI scanner and Multi-photon microscope) co-located with a Cardiac Catheterisation laboratory, an intensive care unit, and preclinical bio-banking with NHS type Cryo storage. The current pipeline of TBRC-supported research projects has a forecasted value of >£20m and underpinned **Bienemann's** ICS**.**

Wolfson Bioimaging Facility and Flow Cytometry Facility: Ashby, Mellor, and **Piggins** have used these state-of-the-art microscopy and flow cytometry facilities (£3.1M capital investment since REF2014), providing access to two both electron microscopes (including Cryo EM) and advanced light microscopes. This enables high-resolution live cell imaging and correlative light and electron microscopy. ~33% of neuroscientists use this facility. In addition, reflecting the growing strength of GW4, and complimenting the jointly funded Cryo EM facility supporting all GW4 institutions, UoB made the strategic decision, supported jointly at the level of the Vice Chancellors of both institutions, to forge stronger relationships with Cardiff across neuroscience. This capitalises on existing collaborations (e.g. **Kehoe US $**300K with Good (Cardiff)**,** on AD; Thapar, (Cardiff, £4M) with colleagues in UoA2 on ADHD), and increasing numbers of shared PhDs (Wellcome Trust, GW4, and Charity funded). Accordingly, UoB has made the strategic decision to support Human imaging research via the outstanding CUBRIC facility in Cardiff, extending our translational imaging pipeline from the Wolfson, through TBRC to CUBRIC. This decision has allowed UoB to rapidly pivot to support local NHS diagnostic backlogs resulting from the pandemic, with an ongoing £1.7M refurbishment and restructuring of the Bristol Clinical Research Imaging Centre (used by ~35% of neuroscientists) by UoB and UHBWT. This will serve new clinical research priorities, including provision of Sleep laboratories and access to 3T MRI scanning for "high priority rapid-response" research, in shared arrangements alongside NHS service needs to solidify human translational research in UoA4.

Advanced Computing Research Centre (ACRC): The Centre includes a highly-parallelized super-computer facility (BlueCrystal and Blue Pebble), operating both Phase 3 (serial-optimised) and Phase 4 (parallel-optimised) nodes supporting more than 800 researchers across UoB, (total investment in the review period £10M, with a further £3M in progress). ~15% of researchers in this UoA are High Performance Computing users, using more than 21,000 CPU hours per month in 2020. The Research Data Storage Facility provides integrated resilient petascale storage to all researchers. ACRC remains central to UoB's commitment (£2M every year) to meet the increasing demands of AI, big data and simulation resources. A funding boost via a £1M Catalyst award from Hewlett Packard Enterprise aligns with the UoB-led GW4 Isambard project, awarded £4.1M by EPSRC in 2020, which has brought a new ARM-based Tier 2 high-performance computing service to UK-based scientists.

Pre-clinical and clinical Neuroscience Research Facilities (Southmead Hospital): This hospital campus was completely rebuilt over the past decade, including an extension (2014, £2M UoB contribution) to the Learning & Research academic building to house several clinical neuroscience groups. This allowed co-location of pre-clinical and clinical neuroscience researchers

of neurological and neurodegenerative diseases in improved shared facilities, accommodated the growing South West Dementia Brain Bank (see below), and provided accessible laboratory facilities for the Bristol Brain Centre (2015, £1.5M refurbishment). This carefully designed facility houses three clinical specialties, their corresponding research activity and a drug infusion suite.

UoB Research Tissue Banks: UoA4 researchers (**Kehoe, Love, Miners, Ashby**) have benefitted from access and expertise at the BMS-hosted Human Tissue Authority (HTA) licensed South West Dementia Brain Bank (SWDBB). It is one of the longest established post-mortem tissue banks and a consistently high performer in the MRC UK Brain Bank Network (UKBBN), which specialises in supporting ageing, dementia and neurodegeneration-related research. SWDBB has provided post-mortem brain materials to national and international neuroscience researchers - since 2014 SWDBB has provided annually, on average, ~4000 separate pieces of tissue to researchers. Other UoA4 relevant biobanks within UoB, include that of the Children of the 90s project (ALSPAC, reported in UoA2).

Bristol Trials Centre (BTC) is a UKCRC-registered clinical trials unit, with a portfolio of over 40 ongoing multi-centre clinical trials. The BTC received £1.8M (NIHR) in 2019/20 to support trials activity, compared to £0.84M in 2014; this increase corresponds with ~30% increase in open NIHR trials in this assessment period. BTC supported **Kehoe's** RADAR study (awarded pre-REF2014, completed 2019) and more recently the Chief PD trial (**Whone** as CI, £2M), and MRC EMCG projects (**Munafò** & **Penton-Voak)**.

The **SPHERE house** is an EPSRC-funded (£15M total funding, **Gilchrist, Munafò & Jones**, co-Is, £3M in current REF period) multi-disciplinary project led by the Digital Health Engineering Research Group (UoA12). SPHERE is designed to significantly advance the state of the art in behavioural data collection at home. The system requirements were determined by a clinicians and clinical scientists and have delivered an integrated suite of data capture technologies, a communications infrastructure, algorithms for data fusion, and a machine learning pipeline to process the raw data into actionable information to support research in a variety of clinical and epidemiological studies. SPHERE was recently deployed to houses of people with Mild Cognitive Impairment (**Coulthard);** the main SPHERE house is currently housing Parkinson's disease patients (**Whone)**.

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

4a Academic collaborations

Snowball metrics indicate that of the 1900+ outputs produced by UoA4 researchers in this assessment period, ~47% have international collaborators. A further 35% have UK collaborators, with Oxford, Cambridge, UCL, KCL and Cardiff the most common UK University partners. Our local NBT and UHBW NHS Trusts are our 2nd and 6th collaborating institutions and are collaborators on ~400 UoA4 papers since REF2014. Our top international collaborator (8th overall) is the National Institutes of Health in the USA. Six percent of our papers are co-authored with collaborators from industry. These figures reflect that BN is, from the ground up, an interdisciplinary organisation that demonstrably spans neuroscience research from bench to bedside, and as a result, collaboration is integral to our work. This is facilitated by the University-wide and Specialist Research Institutes (SRIs, see REF5a), which share similar interdisciplinary and translational agendas for research as described below. Our new BN hubs are explicitly designed to be a funnel through which these

collaborations can occur, promoting interdisciplinary work and allowing rapid progress along translational pathways where appropriate. For example, 'Disruption of sleep-dependent motor memory consolidation in schizophrenia' (Lilly Innovation Fellowship Award, 2016) is a single project drawing from all four hubs, alongside industrial collaborators and GW4 partners (Cardiff). The final elements of translation to humans are possible through our strong links with the NHS in Bristol which sponsored several UoA4 trials (e.g. **Kehoe** (ISRCTN93682878), **Whone,** ISRCTN19880883), **Lightman/Russell** (ISRCTN671937733, ISRCTN22146594), **Wilkins (**EudraCT2017-003084-34)) and are detailed below.

4b. Interdisciplinary links with other strategic UoB institutes and groups

University-wide interdisciplinary research activity (see also REF5a), including this UoA, is effectively fostered through the virtual URIs since the last REF. EBI has administered a range of competitively awarded research funding schemes including: Returning Carers Scheme, Early Career and Senior Fellowships, Clinical Primers, Translational Acceleration and Knowledge Transfer, and Discipline Hopping awards that UoA4 neuroscientists have gained (~£1.6M) from various awards since 2014. Strategically targeted small-to-medium sized awards promoted multi- and inter-disciplinary research including recent rapid-response COVID-19 projects quantifying the psychological impacts and the utility of digital interventions during lockdown. Here UoA4 researchers were key to EBI achieving its role in co-ordinating an institutional response to the COVID-19 pandemic whilst leading new research into the effects of COVID-19 on psychology, mental health, and behaviour (e.g. awards to **Hood** and **Lewandowsky** to investigate COVID-19 related social isolation and privacy concerns respectively). EBI also promoted a suite of projects studying sleep disruption in relation to brain development, chronic pain and schizophrenia liability; and a recent focus on researching and supporting student mental health. In support of BN research, EBI also partners with external funders, e.g. £100K EBI/Rosetrees Trust Mental Health Research funding call (2020), whilst its discipline hopping scheme allowed several UoA4 scientists to collaborate with the MRC IEU (UoA2). Overall, since 2014 several of BN's best young non-clinical and clinical talent gained fellowships schemes and created an environment for effective collaboration with external partners within (e.g. Bristol Health Partners and the NIHR Applied Research Collaboration West (ARC West)) and outside Bristol (e.g. other universities and industry).

4c Links with the NHS, social care services and local councils

Strong links with the NHS and the broader community support successful translation of BN research. The Bristol Brain Centre at Southmead Hospital (part of North Bristol NHS Trust, opened in 2015 after the £1.5M refurbishment (funded by Southmead Hospital Charity, UoB and a local charity (BRACE)) of a building near UoB's Clinical Neuroscience laboratories and the South West Dementia Brain Bank (SWDBB) brings together academic-led multi-disciplinary clinical research teams in clinical neurology (dementia, multiple sclerosis and Parkinson's Disease). This facility enables neuroscientists and NHS clinicians to work with patients researching mechanisms, diagnosis and treatment of common debilitating neurological diseases. The Centre hosts BrAMS (Bristol & Avon MS Service), the MOVE-hIT@NBT (the Health Integration Team for PD and other movement disorders), and the ReMemBr Group (clinicians, researchers, psychologists and nurses involved in dementia research and clinical services improvement), and the main office of BRACE (an independent charity supporting dementia research). The high footfall of patients in the Bristol Brain Centre is an important interface for BN clinical neuroscience research in the NHS services

(11736 patients were seen in the year to April 2020, from which 432 were entered into 36 different research studies).

UoA4 staff interdigitate with NHS colleagues at all levels from NIHR Academic Fellowship and Lectureship to advanced fellowships as well as clinical PhDs and MDs. The interface is overseen by **Iredale** and **Norman** who are respectively Non-Executive Directors of North Bristol Trust (NBT) and University Hospitals of Bristol and Weston (UHBW) NHS Trust. Bristol Health Partners (BHP) was formed (2013) to embody and develop the strategic alignment between UoB, UHBW NHS trust, NBT and Avon and Wiltshire mental Health Partnership, three Clinical Commissioning Groups: Bristol, North Somerset and South Gloucestershire, the two Bristol Universities (UoB and UWE) and the three Local Councils. More recently, Sirona, the newly-commissioned provider of adult community health services in our region, and the Bristol-based NHS Blood and Transplant (NHSBT) have also joined BHP. Strong links with local NHS Trusts (15 UoA4 clinical academic staff) and council organisations promote excellent clinical and translational neuroscience research alongside health education and patient care. The effectiveness of these links is attested to by the 2020 NIHR/NHS award of Academic Health Sciences Centre (AHSC) status (Director: **Wynick** (UoA4 clinical academic, and Joint R&D Director for UHBW and NBT NHS Trusts)); one of only eight such centres in the UK. The AHSC coordinates several Health Integration Teams (HITs), unique to Bristol as multi-disciplinary vehicles to tackle health priorities, and oversees mental health and neuroscience, a key priority area for the West of England Academic Health Science Networks (AHSN). This allows UoA4 researchers to apply our research excellence to healthcare provision, education, and training to improve health. The Dementia HIT, led from the Bristol Brain Centre, warrants mention as a global case study in the London Health Commission's Better Health for London report.

4d External academic and industrial links

A focal point for regional cooperation is the formal GW4 alliance. BN leads on annual GW4 Early Career Neuroscience Day conferences, hosting neuroscience PhD students enrolled on BBSRC SWBio, ESRC SW DTP, and MRC GW4 Biomed DTP programmes and leading the Wellcome Trust GW4 Clinical Academic Training (GW4 CAT) PhD programme.

Highlights of further research collaboration include:

- **The Tobacco and Alcohol Research Group** plays a significant role in the UK Centre for Tobacco and Alcohol Studies, a £3.4M programme of training and research funded by Research Councils UK as part of the Global Challenges Research Fund.
- **Love** served until recently (2013-2020) as the Director of the MRC UK Brain Bank Network (UKBBN) where he oversaw transformative changes in ensuring brain banks work collaborate as a true network where the shared tissue archive is handled with shared best practice. His contributions have facilitated accessibility of resources to researchers in the UK and Internationally. His leadership drove the creation of a bespoke UKKBN database (now with ~1000 registered users), providing clinical, research and neuropathological data alongside tissue, providing a single point of application for researchers to apply for tissue access. UKBBN integrates and links all bank archives with state-of-the-art sample tracking systems that were developed and piloted in Bristol and which now ensure exemplary sample traceability across the network that has been commended by the Human Tissue Authority (HTA). The UKBBN database now provides important data usage and impact data

for funders, the HTA and research ethics committees and since REF2014 UKBBN received 632 tissue requests and supported 484 publications.

- **Kehoe** conceived and led the VICCCS study (Alzheimer's Dement, 2018) to develop new consensus guidelines for the nomenclature and classification of forms of Vascular Cognitive Impairment (VCI). Following this he formed a new VCI Genetics Consortium to undertake the largest (to date) Genome Wide Association Study of VCI, in collaboration with the EU-funded European Alzheimer's DNA Bank (EADB), expected to report in 2021 due to COVID-19 delays.
- **Kehoe** is also PI of Bristol's involvement as a recruitment centre and partnering brain bank (SWDBB) in the Alzheimer's Society/Alzheimer's Research UK co-funded Brains for Dementia Research Initiative (£7.4M overall since 2011 and 5 years committed from 2021).
- MyWorld (**Gilchrist**, co-I**)** has received £30 million from UKRI with a further £16m committed from regional and national and international collaborators. It will provide 1,000m^2 of collaborative R&D facilities, fund innovative research and development projects, improve skills and exploit digital formats to create new experiences in fiction, documentary, games and live performance, enabling the region's creative sector and technology organisations to collaborate and connect regionally, nationally and globally.
- This UoA has hosted nine distinguished overseas visiting fellows though the UoB Benjamin Meaker scheme.

Industrial collaborations: BN anchors many industrial collaborations, including PhD studentships, £0.5M collaborative project grants, >£1M research programmes, and co-funded research hubs. Joint projects undertaken during this submission period include partnerships with Takeda (BBSRC, PI: **Apps**); Boerhinger Ingelheim (BBSRC, PI **Robinson**); Cambridge Cognition (who fund a research hub in PS, and supported a KTP in collaboration with **Penton-Voak** & **Munafò**); Astra Zeneca **(Munafò);** Qinetiq **(Scott-Samuel, Baddeley);** Nestle, GSK, Unilever, Kraft, Mars Wrigley (all with **Brunstrom** and **Rogers**); DREEM ('Coup de Coeur' award, PI: **Coulthard** in a study of sleep in Lewy Body dementia); Renishaw (**Bienemann**); Canon, Neurolixis and Campden Instruments (Behavioural neuroscience R&D, **Jones, Abdala, Warburton**); Neurosolutions (**Pickering**); Aardman animations and the BBC (EPSRC platform grant and IAA grants with **Gilchrist, Ludwig)**. **Molnar** had recent success (BBSRC-funded Knowledge Transfer Fund) enabling researchers in the Pharma firm, Hello Bio, to work in labs of PPN.

Most recently, BN's longstanding and productive relationship with Eli Lilly & Co.'s Centre for Collaborative Neuroscience (involving 5 joint Lilly-Bristol Postdoctoral Fellows and 6 PhD studentships; 2 Lilly Innovation Fellowship Awards and 3 CASE PhD students during submission period) culminated in Lilly selecting Bristol as a UK base for a BN-Lilly Translational Neuroscience Unit, contributing £1M to continue neuroscience projects following closure of their UK research base, and to liaise with Lilly's new 'Neuroscience Next Generation Therapeutics' programme in Cambridge, MA.

4e. Maximising the impact of research through effective communication to the public and key beneficiaries.

UoA4 staff provide high-quality free events to enhance public understanding of science. These include the highly-acclaimed Bristol Neuroscience Festival, which attracts ~5,000 visitors to a three-day research and education programme and has been modelled by other Institutions; the Brain Box Challenge, an award-winning primary school outreach programme engaging with more than 3,000 local school children; and our support of the internationally designated Brain Awareness

Week education programme that has attracted ~5,000 people annually to the weeklong research, education and engagement programme. Since 2014 these events have seen hundreds of neuroscience staff and students engage more than 28,000 local people of all ages with their research and knowledge. Post-event data shows that >90% of visitors to the BN Festival were more aware of the benefits of neuroscience research after attending the event. In 2016 it won the STEMNet regional award for STEM Event of the Year winner. **Robinson** won the 2016 Public Understanding of Neuroscience award from the British Neuroscience Association (BNA).
With ESRC IAA funding **Hood** founded Speakezee.org - the world's largest searchable database of expert speakers enabling speakers to engage with their audience and for organisers to find relevant experts to talk at their event.

4f. Prestige indicators of national and international research citizenship.

Honours, Fellowships, and other awards:

- **Collingridge:** Brain Prize (2016) and CBE (2019).
- **Lightman:** FRS (2017); President of the British Neuroscience Association (2016-2019).
- **Lumb:** President of the Physiological Society (1st female president); Patrick Wall Lecture by the British Pain Society.
- **Apps**: Royal Society Leverhulme Trust Senior Research Fellowship (2014-15).
- **DasGupta:** Sir Henry Dale Fellowship (2020-2025).
- **Jones:** MRC Senior Fellow to 2016 then Wellcome Trust Senior Fellow (2016-2022).
- **Pickering**: Wellcome Trust Senior Clinical Fellowship (2009-2016).
- **Skatova:** UKRI Future Leader Fellow (2020) and Turing Fellow.
- **Anastasiades:** NARSAD Young Investigator Award for Brain and Behavior Research Foundation (2020).
- **Domanski**: Crick-Turing Institute Fellowship (2020-2022).
- **Maynard:** ESRC Outstanding Early Career Impact Prize (2014).
- **Haworth**: Philip Leverhulme Prize (2018) and the British Psychological Society Spearman Medal for outstanding published works in Psychology (2017).
- **Hood**: British Psychology Society Distinguished Contribution to British Developmental Psychology.
- **Lewandowsky**: Humboldt Research Award, Alexander von Humboldt Foundation, Germany, 2019; Fellow, Association for Psychological Science, and Fellow, Academy of Social Sciences (UK), both from 2017.
- **Munafò**: Presidents' Award for Distinguished Contributions to Psychological Knowledge (2017) from the British Psychological Society.
- **Mickes**: Psychonomic Society Early Career award in 2018.
- **Rolinski:** World Sleep Society Young Investigator Award in 2015.

4g. Other contributions to the discipline:

Journal editorships: Over this assessment period, the majority of UoA4 members have been actively involved in academic publishing, with 41 holding or having held significant editor/editorial board roles with scientific journals including **Abdala** (Autonomic Neuroscience), **Bowers** (Cognition and Memory), **Coulthard** (Frontiers in Dementia and Neurodegeneration), **Damian** (Quarterly Review of Experimental Psychology), **Jarrold** (Developmental Science), **Love** (Alzheimer's Research and Therapy), **Ludwig** (Quarterly Review of Experimental Psychology), **Lumb** (Neuroscience), **Marrion** (Editor, Concise Guide to Pharmacology), **Munafò** (Editor-in-Chief, Nicotine and Tobacco Research), **Penton-Voak** (British Journal of Psychology), **Robinson**

(Pharmacology, Biochemistry, and Behavior), **Scolding** (Multiple Sclerosis), **Turk** (Memory), and **Warburton** (Brain and Neurosciences Advances). A further 26 UoA4 researchers serve on one or more editorial boards.

Membership of grant and fellowship awarding bodies: Approximately one third of the members of this UoA (n=28) make significant contributions to assessment and decisions on psychology and neuroscience grant funding and serve or have served on grant and fellowship review panels for UKRI, Wellcome Trust, Royal Society, leading Medical Charities and European funding bodies. Many of our staff serve on committees and panels for funders. Examples include **Gilchrist (**EPSRC advisory panel), **Jarrold** (ESRC committees including Future Leaders, Doctoral Training Programmes, and ESRC Panel A), **Mellor** and **Munafò** (MRC Neuroscience and Mental Health Board), **Hodge, Molnar, Piggins,** and **Warburton** (BBSRC), **Bashir**, **Chadderton**, **Robinson** and **Jones** (Wellcome Trust Basic Science and Fellowship Interview panels), **Lumb** (Versus Arthritis), **Robinson** (Royal Society), **Uney** (Parkinson's UK)**, Wynick** (Diabetes UK), **Apps** and **Bashir** (REF panel membership). **Munafò** chairs the MQ Mental Health Fellows committee and Cancer Research UK Prevention and Population Hearth research committee, **Coulthard** serves on the steering committee for the Brain Health Clinic Consortium hosted by Biogen, and the Scientific Advisory Board for Slowave Therapeutics. **Kehoe** has been a member of the Alzheimer's Society Research Strategy Council.

Committee membership of professional bodies, charities and trusts: During the review period **Lumb** served as President of the Physiological Society, **Lightman** as President of the British Neuroscience Association (and now Trustee), **Piggins** (British Neuroscience Association including as **Piggins** BNA Festival of Neuroscience organiser), **Brennan** (President of European Chemosensory Research Organisation), **Jones** (Department of Health 'Development of a Ten Year Strategy for Mental Health – Basic Science' Working Group).