Institution: University of Edinburgh

Unit of Assessment: UoA4: Psychology, Psychiatry and Neuroscience

1. Unit context and structure, research and impact strategy

1.1 Overview

Edinburgh Neuroscience is a vibrant community of 201 independent researchers in neuroscience, psychology and clinical psychology who work together with a shared vision to (i) discover new knowledge of the workings of the brain and mind across the life-course, in health and disease, and (ii) translate this into individual and societal health and wealth gains. To achieve this we have, since 2014, invested strategically in growing and promoting a deeply collaborative and cross-disciplinary culture that cuts across psychology, psychiatry and neuroscience in three themes that are linked to life-course (Fig. 1.1). Our strategic growth since 2014 in staff number (56% increase) and diversity (now 40% female, 11% BAME) and strategic investment received (£257M; 2.5-fold increase) has shaped and exploited exciting new opportunities in data-driven knowledge, innovation, translation and impact.

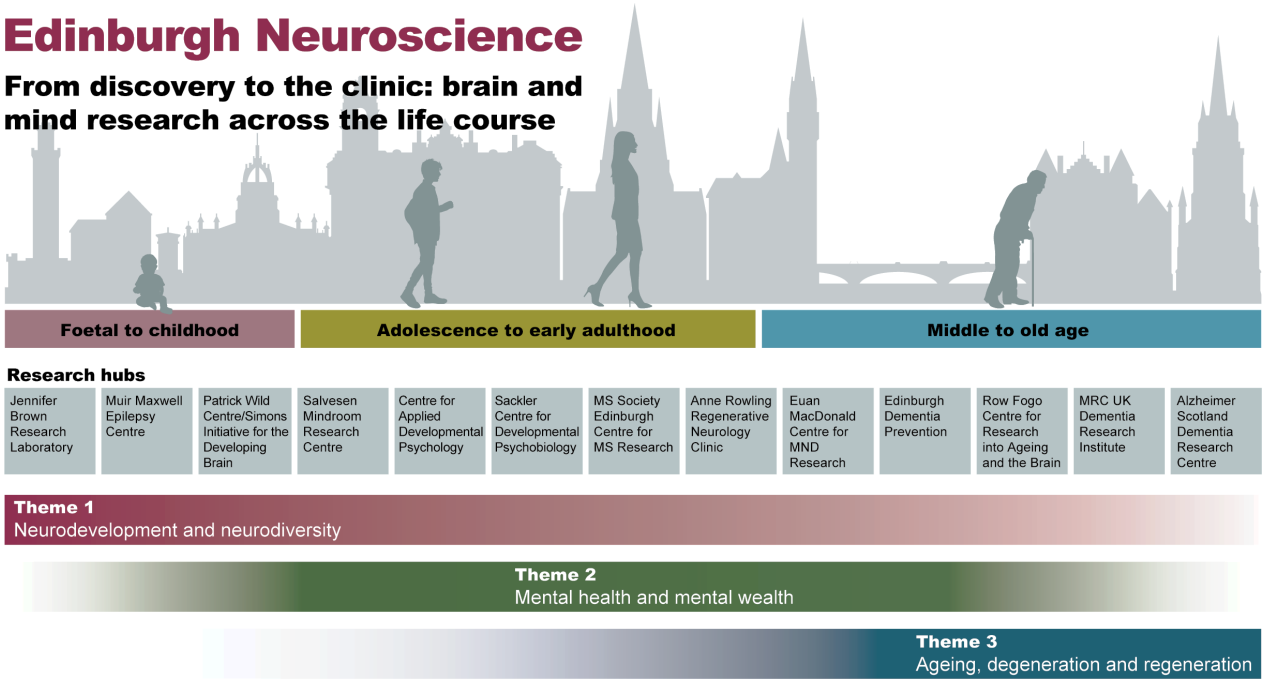

***Fig. 1.1**: Our integrated life-course approach is underpinned by inter-disciplinary research hubs*

1.2 Research and impact strategy

Edinburgh Neuroscience aims to deliver world-class discovery-to-translation research into the brain and mind across the life-course, which is:

- Cross-disciplinary, collaborative, resilient and sustainable
- Conducted openly and with the highest standards of ethics and integrity
- Influential for the policy and practice of medicine and healthy living across the life-course

This research vision is underpinned by three important concepts: i) basic science broadens our understanding of the brain and underpins advances in treatments; ii) brain disorders do not occur in isolation from the wider body and are closely linked to developmental, psychological and socio-cultural factors, often variably affecting different genders and ethnicities; and iii) although brain conditions/variations across the life-course are distinct, they share core clinical and neurobiological features and psychosocial influences. For example, dysregulation of the innate immune response is common to autism spectrum disorders, major mental illness and neurodegeneration.

These foundational concepts have inspired us to invest in a fluid inter-disciplinary environment where multiply-affiliated researchers work in hubs led by the science rather than their discipline, organisational structure or role. These wide-ranging teams — comprising basic, clinical, psychological and/or translational researchers, as well as health professionals, industrial partners, students and technicians — are poised to shape, as well as respond rapidly and flexibly to changes in, the research landscape.

Our strategic aims during this REF period, and the success we have had in achieving these, were:

Grow, strengthen and diversify our research community

Edinburgh Neuroscience has grown substantially since the last REF. We have increased the number and diversity of staff and students, support for translation and impact, internal and external funding and engagement (detailed in subsequent Sections). Headlines are:

- 56% increase in independent researchers including 48 early-career researcher (ECR) appointments (42% female, 10% BAME). We also appointed 12 new Chairs (25% female, 8% BAME)
- £27M in successful personal fellowships (31% ECR, 34% female, 7% BAME)
- 2.5-fold increase in strategic awards, plus £305K internal seedcorn funding to 114 awardees
- three new flagship PhD programmes; £9M from Wellcome (plus £2M from UoE) for Translational Neuroscience programme (54 students over 9 intakes, initial award 2016, renewal 2020–2024), £450K from Scottish Government for SPRINT-MND/MS programme (12 students over 3 intakes, 2017–2019); £2M for Simons Initiative for the Developing Brain PhD programme (28 students over 8 years)
- 12.3FTE new posts in research support: science management, funding specialists, impact, commercialisation, information governance, communications, knowledge exchange and public engagement

Develop cross-disciplinary teams anchored around major brain conditions across the life-course

Building on our highly successful model of specialist research hubs, with £135M of external investment (Section 3.1) we have grown and created additional hubs, bringing our total to 13 (Fig. 1.1). New hubs include (i) £32M Simons Initiative for the Developing Brain; (ii) £23M Edinburgh node of the UK Dementia Research Institute (UK DRI) and (iii) £58M Edinburgh Dementia Prevention.

Inter-disciplinary research membership provides strength in diversity and improved validity of research by using multiple approaches to a single problem, as well as streamlining discovery-to-translation pipelines. Furthermore, they provide focus and impetus for researchers, a clear link to patients and charities and a 'hook' for knowledge exchange and public engagement. To ensure the focus of all our research hubs reflects expressed patient need and public health priorities, we have embedded engagement with patients, charities and policy-makers into our practices.

The success of our hub model can be evidenced by: (i) additional funding leveraged (Section 3.1), (ii) sparking and facilitation of innovative and cross-disciplinary work (Fig. 1.2); (iii) opportunities for funded studentships and ECR mentoring (Section 2); (iv) improved two-way engagement with patients and charities (Section 4); and (v) the transformational impact that our research is having on policy, practice and health and welfare outcomes across the UK and beyond (REF3s).

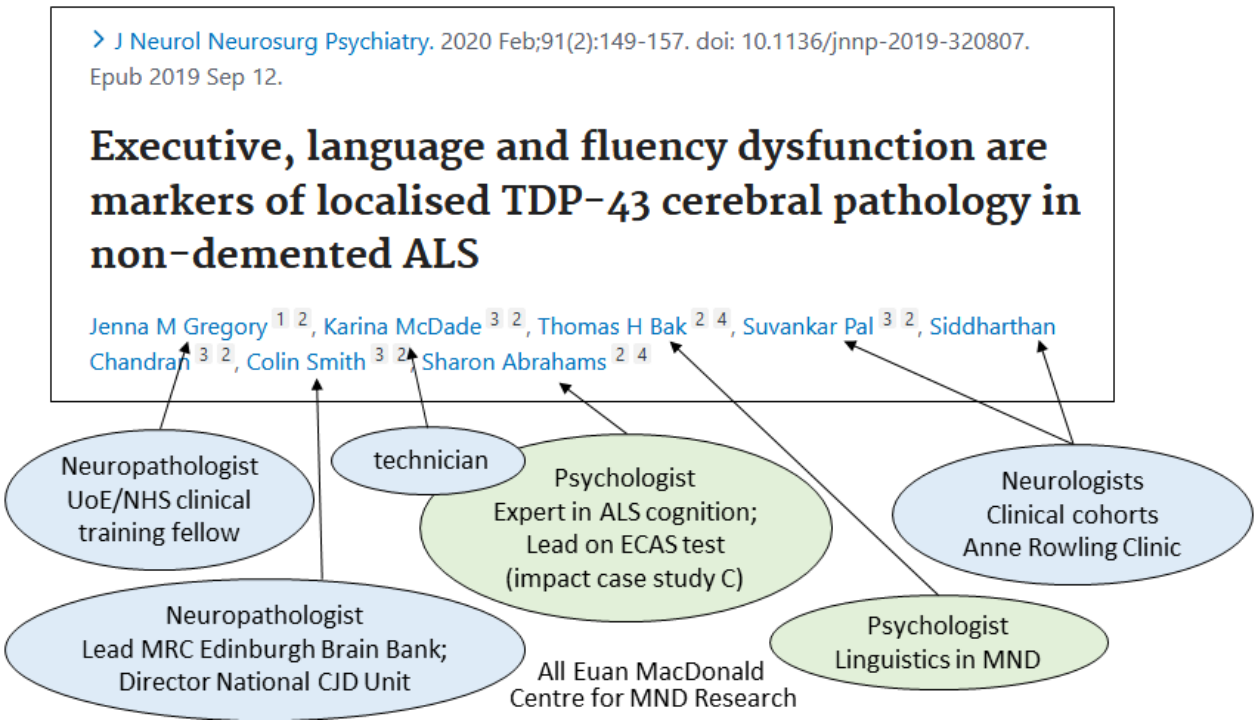

***Fig. 1.2**: The authorship list on a publication from the Euan MacDonald Centre exemplifies diversity, inter-disciplinarity and cross-theme collaboration. Green = research theme 2; blue = research theme 3. Authorship 42% female including first and senior author; 42% BAME*

Embed impact as an integral part of the research journey

The research highlighted in our impact case studies has resulted in changes to 58 policy guidelines, with over £228M a year saved by the NHS and 7 million people reached through education impact. In this REF period we have evolved our culture to foster impact, through transformed UoE support units for research grants, translation and commercialisation, clinical research studies and trials, patient and public engagement (Sections 3.3, 3.4) and by offering competitive seedcorn funding specifically targeting translation and impact (Section 3.2). We have employed 1.9FTE impact professionals to proactively identify potential impact from publications and work one-to-one with academics and research support to drive, deepen and record impact.

Assessment of impact is now mandatory in the annual Performance and Development Review for academics, with metrics recorded systematically in five categories: (i) practice and practitioners; (ii) policy; (iii) commercialisation and translation; (iv) public, community and patient engagement; and (v) education. Staff can then be rewarded for achieving impact; for example, the promotion of **Fletcher-Watson** to Chair (Section 2.2.1) considered her research on the use of technology by children with autism, as well as her interactions with Scottish Government, the BBC and the National Autistic Society to improve education and quality-of-life for these children.

Increase external engagement through research, training and knowledge exchange

New initiatives (detailed in Section 4) include:

- International research-led collaboration and investment (e.g. £36M Zhejiang University-University of Edinburgh (UoE) Institute; £3.8M Medical Research Council (MRC) funded Generation Malawi project; two Fondation Leducq Transatlantic Networks of Excellence (€6M each)
- Expansion in online postgraduate teaching and CPD programmes (Neuroanatomy, Imaging, Stem Cells and Translational Neurology (1,493 students enrolled 2019/20)
- New and strengthened relationships with charities and the third sector; our researchers have direct involvement with 69 patient-facing charities including Alzheimer's Society, MS Society and Stroke Association, and have established two new charities
- Emphasis on inclusion of patients/public throughout the research journey, from focus groups and lived-experience panels convened before grant application, to promotion of research using web, blogs and podcasts, press and social media

Drive collaborative inter-disciplinary research through infrastructure investments

We have made great strides towards coalescing Edinburgh Neuroscience on three campuses: Royal Edinburgh Hospital (Psychiatry), George Square (Psychology) and BioQuarter, Edinburgh's clinical, research and translation campus (detailed in Section 3). Clinical neuroscience is now co-located with the new £150M NHS Lothian Department of Clinical Neurosciences and Royal Hospital for Children and Young People (opened 2020). Basic neurosciences will follow, fuelled by £12.1M investment in the future Brain-Body Institute.

1.3 Research Themes

Our research is focussed on three themes that span the life-course (Fig. 1.1):

Theme 1: Neurodevelopment and Neurodiversity (foetal to childhood)
Theme 2: Mental Health and Mental Wealth (adolescence to early adulthood)
Theme 3: Ageing, Degeneration and Regeneration (middle to old age)

Our 13 research hubs are centred on one theme but span the other two. Researchers are strongly encouraged to join any hub that supports and benefits their science; thus, many are members of more than one.

1.3.1 Theme 1: Neurodevelopment and Neurodiversity

Fig. 1.3: *Theme 1 – key metrics*

Research Strengths

This theme encompasses pre-clinical, clinical and psychology research to address brain development, neurodiversity and disorders, and their impact on learning, education and behaviour (see Fig. 1.3 for key metrics). Four research hubs underpin this theme. The £32M Simons Institute for the Developing Brain led by **Kind**, integrating 30 Principal Investigators (PIs), aims to discover mechanisms underlying autism. The £2M Theirworld Edinburgh Birth Cohort (Section 3.3.3), led by Boardman (UoA1) as part of the Jennifer Brown Research Laboratory, with co-Investigators (co-Is) including **Fletcher-Watson**, **Bastin**, **Chandran**, **Chin**, is a 25-year study of brain health in 400 premature babies. The £5M Salvesen Mindroom Research Centre, led by **Fletcher-Watson**, is focussed on research and practice to benefit children and young people with learning difficulties. The Muir Maxwell Epilepsy Centre led by **Chin** investigates the causes of childhood epilepsy and develops new treatments.

Investment in People

New appointments since 2014 include **Cobb** (molecular neuropathology of neurodevelopmental disorders)**, Czopka** (oligodendrocyte-neuronal communication), **Kyranides** (ECR; deviation from normative development), **Wang** (learning and memory mechanisms), **Brunton** (prenatal maternal stress in foetal brain development), **Gillespie-Smith** (social and cognitive development), **Girard** (social-behavioural development), **Menzies** (neural correlates of appetite control), **Luksys** (ECR; computational mechanisms of learning, memory and decision making); **A.Murray** (ECR; developmental aspects of mental health), **Obsuth** (developmental psychology and psychopathology) and **Sharpe** (development of body dissatisfaction across childhood and adolescence).

Vitality and Sustainability

Fellowships awarded include four Wellcome Investigators (**Brophy, R.Morris, Nolan, Cousin**), a Wellcome Senior Research Fellowship (**Lyons**), a British Academy Newton Advanced Fellowship (**Rabagliati**), three Wellcome Sir Henry Dale Fellowships (**Osterweil, Rochefort, Surmeli**), a Biotechnology and Biological Sciences Research Council (BBSRC) New Investigator Fellowship and Alzheimer's Research UK Senior Fellowship (**Wang**), an Epilepsy Research UK Fellowship (**Sulser**), a Royal Commission 1851 Fellowship (**Padamsey**) and an Economic and Social Research Council (ESRC) Open Research Area grant (**Chevalier**).

1.3.1.1 Neural development, circuit formation and function

Researchers in this sub-theme aim to elucidate how the brain develops, neurons differentiate and form functioning networks. The fundamental processes targeted include action, perception and learning.

Price and **Pratt** have found unprecedented subclass diversity in cortical interneurons that is determined much earlier than previously thought **[Science 2018]**. **Duguid** found that cerebellar interneurons control the activity of Purkinje neurons that underpin simple and complex motor behaviours **[Nat Comm 2016]**. **Rochefort** and **Padamsey** identified how visual input and locomotor activity affect the activity of cortical neurons, applying *in vivo* imaging of mouse visual cortex **[eLife2019]**. Using *C.elegans*, **Busch** showed that high neural activity accelerates the decline of cognitive plasticity with age **[eLIFE 2020]**. Using a *Xenopus* tadpole model, **Zhang** identified a cation current in descending interneurons that is pivotal in the control of locomotor patterns **[Curr Biol 2018]**. **Nolan** and **Sürmeli** found that specific transcription factors regulate the differentiation of interneurons in the entorhinal cortex, influencing signal processing during learning **[eLIFE 2020; Neuron 2015]**.

Investigating the role of neuronal activity and plasticity within networks during development and how this contributes to autism, **Kind**, **Osterweil**, **Booker** and **Wyllie** identified hyperinnervation of dendrites as the underlying mechanism of hyperexcitable circuits in Fragile X patients and autistic people **[Nat Comm 2019a, b; Neuron 2017; Brain 2019]. Cobb** develops gene therapy approaches for monogenetic developmental conditions such as Fragile X and Rett Syndrome and identified pivotal target binding sites on the MeCP2 protein **[Nature 2017]**.

Grant and **Komiyama** characterised the synaptome of the mouse and human brain across the lifespan **[Science 2020]** and found that areas controlling higher cognitive function contain the greatest synapse diversity, and mutations causing cognitive disorders reorganise synaptome maps **[Nat Neurosci 2018]**. **Cousin** and **Smillie** study regulation of synaptic vesicle formation and identified VAMP4 as essential for activity-dependent endocytosis **[Neuron 2015]**. **Deary** identified genetic loci that influence cognitive function and implicate a role for neurogenesis and myelination in intelligence **[Nat Comm 2018**; **Mol Psychiatry 2019]**.

Axonal and network functions are largely determined by the myelination of axons yet many principles of myelin formation and maintenance are not yet known. Using zebrafish, **Lyons** showed electrical activity-dependent myelination **[Nat Neurosci 2018]** and **Czopka** identified functionally distinct subgroups of oligodendrocyte precursors **[Nat Neurosci 2020]. ffrench-Constant** showed that oligodendrocytes also responded to the physical cues provided by axon size **[Curr Biol 2015]** and **Meijer** identified transcription factor Zeb2 as essential for peripheral myelination and nerve repair **[Nat Med 2015]**.

Long-term potentiation has long been recognised as essential for the formation of memories. **R.Morris** coined the concept of 'silent learning', having found that new memories can be formed through network computation of dendritic activity in the absence of cell firing **[Curr Biol 2018]**. Whether everyday events are committed to long-term memory is in part determined by the co-occurrence of a novel event. **Duszkiewicz** and **R.Morris** reported that this novelty is encoded by TH1-positive neurons in the locus coeruleus **[Nature 2016]**.

Brain function is influenced by hormonal and other signals from the body. **Leng** showed that touch promotes inter-female communication via activation of parvocellular oxytocin **[Nature Neurosci 2020]**. **Auyeung** showed elevated foetal steroidogenic activity in people later diagnosed with autism spectrum disorders **[Mol Psychiatry 2015]**. **A.Murray**, **Booth and Auyeung**'s study of people with ADHD found that females showed an increase in symptoms in adolescence while males' symptoms increased throughout childhood **[Dev Sci, 2019]**.

1.3.1.2 Cognitive and social development

This sub-theme comprises researchers concerned with the development of cognitive control, communication, neurodevelopmental disorders, early infant development and development of criminality.

Doumas investigates how children and adults represent and use relations to solve problems, and has developed and tested a computational model of how constituent parts are bound into relational structures **[Phil Trans B, 2020]**. **Rabagliati** investigates how we translate concepts into words and sentences. His team demonstrated that children prepare responses by predicting what the other is about to say **[Psych Sci 2019]**.

Chevalier found that increasingly efficient cognitive control during childhood is supported by more differentiated recruitment of prefrontal cortex as a function of cognitive control demands **[Dev Cog Neurosci 2019]**. He also found that 3-year-old children fixated on target objects before they fixated on cues that indicated how they should act, whereas 12-year-olds and adults fixated on the cues first, demonstrating a developmental shift in information prioritisation **[Dev Sci 2018]**.

Applied psychologists investigate the basis for abnormal development and precursors of later mental health difficulties. **Girard** identified, in a population study, limited positive impacts of breastfeeding for children's cognitive and noncognitive development **[Pediatrics 2017]**. **Gillespie-Smith** relates core socio-cognitive characteristics and their impact on wider areas of functioning, and identified key targets for early intervention **[J Child Psychol Psychiatry 2016]**.

Fletcher-Watson charts psychological development including intervention design and evaluation, focussing on autism and social cognition. With Boardman (UoA1) she showed in a cohort study of 26,341 Scottish children that neighbourhood deprivation and lower gestational age were associated with additive risks for speech, language and communication concerns in toddlers **[JAMA Netw Open 2019]**.

Sharpe identified developmental precursors of emerging eating disorder and depression in preadolescence linked to negative affect and early body dissatisfaction **[J Child Psychol Psychiatry 2015]**. **Chan** identified key neurophysiological and neurofunctional characteristics identifying individuals at high risk of depression **[J Child Psychol Psychiatry 2015]**.

1.3.2 Theme 2: Mental Health and Mental Wealth

Research Strengths

This theme unites research into individual differences in personality and cognitive function, risk factors and disease mechanisms to better understand the behavioural and neurobiological processes underlying psychological resilience, and psychological and psychiatric risk (see Fig. 1.4 for key metrics). Underpinned by the Centre for Applied Developmental Psychology (Lead: **Williams**) and the Sackler Centre for Developmental Psychobiology (Lead: **A.Mcintosh**), we have particular strengths in genome-wide meta-analysis in large human cohorts, particularly the world-leading Lothian Birth Cohort studies that examine individual differences in relation to environment and genetics, and Generation Scotland, which is uncovering the genetic architecture of depression (Section 3.3.3).

Fig. 1.4: Theme 2 – key metrics

Investment in People

New appointments since 2014 include **Bramley** (ECR; computational models of human learning, problem solving and intelligence); **D.Mirman** (neural organisation of spoken language processing); **J.Mirman** (social determinants of health and well-being for vulnerable populations); **Hoffman** (processes of semantic cognition), **Silson** (ECR; functional organisation of human visual cortex) and **Stanton** (cognitive and affective aspects of close relationship dynamics).

Vitality and Sustainability

Grants and fellowships awarded include: Wellcome £5M renewal of Generation Scotland, a 40K-person resource to study the genetic basis of common complex diseases (Porteous UoA1, **Deary**, **A.McIntosh**); MRC £3.8M for Generation Malawi, a study of family, maternal and childhood mental health (**A.McIntosh**, **Macbeth**, **Stewart**), a Wellcome Sir Henry Dale Fellowship (**Gkogkas**), National Institutes of Health USA (NIH) CReATe Clinical Research Fellowship (**McHutchison**), Royal College of Physicians Edinburgh Sim Fellowship (**Rooney**) and a British Academy/Leverhulme Senior Research Fellowship (**Branigan**). Awards include a Philip Leverhulme Prize for 'Understanding and attributing mind, humanity and morality' (**Loughnan**) and a Marie Skłodowska-Curie Actions Innovative Training Network: COBRA to investigate mechanisms that allow conversation to unfold (**Pickering**).

1.3.2.1 Cognitive processing and individual variation

Researchers in this sub-theme study adult cognition and cognitive neuroscience primarily from the perspective of processing, complementary to other groupings researching development and decline. The work focusses on language and communication, perception, memory, concept use and social cognition.

Branigan and **Pickering** demonstrated that experimental tests of the tendency to repeat linguistic structure lead to a theory of language representation that is superior to one based on grammaticality judgements **[Behavioral Brain Sci 2017]**. The Continuation Task, based on this research, was developed for teaching English in China, and has reached over 3 million students **[Case Study E:Interactive Alignment]**. Such representations help explain how people use language production to predict what they are going to hear **[Psych Bull 2018]**. **D.Mirman** used imaging and behavioural assessment to dissociate linguistic meaning from form and recognition from production **[Nat Commun 2015]**. **Silson** used fMRI to explain apparent cortical redundancy in representational distinctions in the visual field **[J Neurosci 2015]**.

Bramley investigates human learning and developed a computational model of causal structure in which learners represent only a single global hypothesis that they update locally as they gather evidence **[Psych Review 2017]**. **Hoffman** used fMRI to show that the neural correlates of semantic cognition and its executive control dissociate from the default mode network **[Proc Natl Acad Sci USA 2015]**, informing a unifying, neurally plausible computational model of normal and impaired semantic cognition **[Psychol Rev 2018]**.

Using novel psychophysical methods, **R.McIntosh** showed that the tendency for people with least skill to overestimate most (Dunning-Kruger effect) is not driven by metacognitive differences, but by statistical artefacts **[J Exp Psychol Gen 2019]. Logie** found strong dual-task and suppression costs that helped adjudicate among theories of working memory **[J Exp Psychol Learn Mem Cogn 2018]**.

Stanton found effects of positive intimacy relationship experiences on individuals with attachment avoidance **[J Pers Soc Psychol 2017]**, suggesting simple techniques to support relationships. **Templeton** showed that disgust (in response to smelling sweat) is attenuated for people with a shared group identity and affects their willingness to interact **[Proc Natl Acad Sci USA 2016]**.

A large group of researchers studies the psychology of personality and other individual differences. **Luciano** discovered genes and biological pathways underlying neuroticism [**Nat Genet 2017]**. **Mottus** studied twin pairs and found that personality nuances contribute to individual difference and prediction of outcomes **[J Pers Soc Psychol 2017]**. **Weiss**' work on non-human primates showed association between specific personality traits and longevity in chimpanzees, with higher 'agreeableness' related to long life in males **[eLife 2018]**.

Cox conducted the largest single-sample study of structural and functional sex differences in the human brain **[Nat Commun 2016]**, and **Davies** reported the world's largest genetics study of cognitive function and educational attainment, identifying genome-wide genetic variants associated with reasoning and cognitive processing speed **[Mol Psychiatry 2016]**. **Harris** was the first to map the extent of pleiotropy between cognitive function and physical/mental health **[Mol Psychiatry 2016]**. **Bates** found an interaction between genetics, socioeconomic status and intelligence/attainment scores, which is pronounced in the US but not in Europe or Australia **[Psychol Sci 2016]**.

Stone and Carson (both NHS) are world-leaders in the study of functional neurological disorders (Sections 4.1.3, 4.1.4 and **Case Study D:Functional Neurological Disorders**). They were co-Is on the Cognitive Behavioural Therapy (CBT) for Adults with Dissociative Seizures trial (King's College London-led, 2014–2018), which showed that while CBT did not reduce seizure frequency, it did confer improvements in secondary outcomes such as quality-of-life and psychosocial functioning **[Lancet Psychiatry 2020, PMID:32445688]**.

1.3.2.2 Risk factors in mental health

The span of mental health and resilience research within this sub-theme extends from early-life to adolescence, adulthood and later life.

Lawrie, Whalley and **Chandran** found dysregulation of key pathways controlling development and morphogenesis in oligodendrocytes derived from induced pluripotent stem cells (iPSCs) from people carrying a genetic anomaly that increases the risk of schizophrenia **[Mol Psychiatry 2019]**. **Lawrie** probed the impact of genetic risk factors on brain structure and function in schizophrenia and related disorders **[Biol Psychiatry 2015]**. **Owens** employed human imaging to explore correlations between grey matter loss and negative symptoms in learning-disabled adolescents at risk of psychosis **[Br J Psychiatry 2016].** Physicist **Bastin** develops magnetic resonance imaging (MRI) methodology that is applied to longitudinal studies of the brain's white matter structure across the life-course, including the influence of conditions such as schizophrenia **[Neuroimage 2018]**.

A.McIntosh applies genome-wide meta-analysis approaches to large human cohorts such as Generation Scotland to uncover the genetic and structural architecture of depression, identifying the role of prefrontal brain regions in depression **[Nat Neurosci 2019].** He is co-I on a €6M EU Horizon 2020 programme (Lead: Oslo) to predict comorbid cardiovascular disease in individuals with mental health disorders. **Whalley** uses the latest neuroimaging and genomic approaches (genetic, epigenetic and multimodal imaging) to explore mechanisms underlying psychiatric disorders **[Biol Psychiatry 2019; Transl Psychiatry 2020]**.

Williams, funded by the SPCA and DEFRA, showed attachment to pets was associated with a beneficial effect on quality of life of adolescents **[Attachment and Human Dev 2017].** Funded by National Institute for Health Research (NIHR) and MRC (£4M) **Schwannauer** used machine learning to develop prognostic prediction models for people with first-episode psychosis **[Lancet Digit Health, 2019]**. **J.Mirman** conducted randomised controlled trials of low-intensity interventions targeting adolescent risk-taking, demonstrating a reduction of harmful behaviours in relation to driving performance as well as sexual behaviours and alcohol use **[JAMA Netw Open, 2019]**. **Quayle** studies psychological factors related to online sexual exploitation of children and young people. Three studies on indecent images of children led to the joint coordination of a G8 meeting plus World Health Organiation (WHO) and United Nations (UN) guidance on technology-mediated sexual crimes **[Child Abuse Review, 2018]**.

1.3.3 Theme 3: Ageing, Degeneration and Regeneration

Fig. 1.5: Theme 3 – key metrics

Research Strengths

This theme integrates laboratory, epidemiological and clinical research to understand the pathobiology of disorders of the ageing brain and its protection and regeneration. Key disease areas include cerebrovascular disease, motor neuron disease (MND), multiple sclerosis (MS) and the dementias (see Fig. 1.5 for key metrics). The theme includes the new £23M MRC UK DRI (**Hardingham**), the renewed National Creutzfeldt-Jakob Disease (CJD) Research and Surveillance Unit (£11M; **Smith**), MS Society Edinburgh Centre for MS Research (£4M for two renewals; **Chandran**, **ffrench-Constant**), Euan MacDonald Centre for MND Research including the MND-SMART platform trial (£4.2M; **Chandran**), Row Fogo Centre for Research into Ageing and the Brain (£0.9M; **Wardlaw**), Edinburgh Dementia Prevention (£58M; **C.Ritchie**), Alzheimer Scotland Dementia Research Centre (£0.8M; Starr (deceased), Russ (NHS)) and Anne Rowling Regenerative Neurology Clinic (£15M second donation; **Chandran**).

Investment in People

New appointments since 2014 include **Crow** (Chair of Genomic Medicine); **Priller** (UK DRI, Chair of Brain Inflammation and Repair); **Diaz-Castro** (ECR, function and dysfunction of the blood-brain barrier)**, Durrant** (ECR, synaptic pathology of Alzheimer's disease); **Gan** (ECR, neural circuit dynamics in dementia); **Selvaraj** (ECR, mechanisms of selective vulnerability in motor neurons); **Breen** (ECR, circadian rhythm disruption in Alzheimer's and Parkinson's); **Pal** (clinical trials in neurodegenerative disorders).

Vitality and Sustainability

In addition to the hubs mentioned above, significant awards include: £7.5M from Dementias Platform UK (**Wardlaw, Chandran, Deary**), Wellcome Investigator (**ffrench-Constant**), Wellcome Senior Clinical Fellowship (**Hunt**), Wellcome Clinical Career Development Fellowship (**Breen**), European Research Council (ERC) Consolidator Award (**Spires-Jones**), UK DRI Momentum Award (**Priller**), two Chief Scientist Office Senior Clinical Fellowships (**Mahad, Whiteley**), Alzheimer's Research UK Senior Research Fellowship (**Fowler**), Race Against Dementia Dyson Fellowship (**Durrant**), Daphne Jackson Trust Research Fellowship (**James**), Stroke Association Clinical Lectureship (**Mair**) and Postdoctoral Fellowship (**Wiseman**), £0.5M Chief Scientist Office SPRINT-MND/MS five-HEI PhD programme (**Chandran**).

1.3.3.1 Neuronal, glial and vascular interaction

Although the clinical expression of neurological disease reflects dysfunction and/or loss of neural circuits, the underlying pathobiology is often one of failed brain homeostatic mechanisms and maladaptive responses of neurogliovascular cell types. Accordingly, this cluster unites world-leading expertise in the biology of the three principal components of the brain: neurons, vasculature and glia, to better understand the cellular autonomy of neurological disease and its potential regeneration. **Priller** showed spatial and temporal heterogeneity of mouse and human microglia including in MS tissue **[Nature 2019]**. **ffrench-Constant** and **Jaekel** used single nucleus RNA to show both interspecies difference and oligodendrocyte heterogeneity in MS **[Nat Med 2018; Nature 2019]**. **Diaz-Castro** identified astrocyte heterogeneity in Huntington's disease **[Sci Transl Med 2019]**. **Wardlaw** showed that endothelial dysfunction is a reversible cause of white matter pathology in a model of small vessel disease **[Sci Transl Med 2018]**. **Hardingham** showed that neuronal activity controls astrocyte gene expression **[Nat Commun 2017]**. **Gillingwater** showed widespread vascular abnormalities in spinal muscular atrophy **[Ann Neurol 2016]** and **Miron** found that targeting pro-inflammatory microglia promotes regenerative remyelination **[Nat Neurosci 2019]**.

Edinburgh Neuroscience has a long-established record in human neurovascular imaging research and large multi-national clinical trials. **Wardlaw**, **Dennis** and **Sandercock** showed that MRI is not cost-effective for secondary stroke prevention after a transient ischaemic attack or minor stroke **[Ann Neurol 2014, PMID:24085376]**. **Wardlaw** and colleagues previously demonstrated that computerised tomography (CT) scanning was the most cost-effective; this has changed guidelines and clinical practice internationally (10% increase in UK stroke patients receiving an immediate CT scan 2015–2019), and is estimated to result in 42,000 more quality-adjusted life-years in the UK, reducing the cost of stroke to the NHS by £1.1–2.2 billion per year **[Case Study H:Stroke imaging]**.

Dennis showed the benefit of intermittent pneumatic leg compression after stroke to prevent deep vein thrombosis. This is now embedded in clinical guidelines and practice and is estimated to save 786 UK lives per year **[Lancet Neurol 2014; Case Study F:Intermittent Pneumatic Compression]**. **Mair** showed that pre-hospital administration of glyceryl trinitrate by ambulance crews in acute stroke did not improve functional outcomes **[Lancet 2019]**. **Salman** showed in the PATCH and RESTART trials that antiplatelet therapy but not platelet infusion is beneficial in the long-term management of intracerebral haemorrhage **[Lancet 2014, 2016, 2019; Lancet Neurol 2019]**. The finding that survivors of brain haemorrhage need not stop taking antiplatelet drugs is expected to have widespread clinical benefit. **Whiteley**, **Sandercock** showed that irrespective of

age, alteplase significantly improves stroke outcome if delivered within 5 hours of stroke onset. This research has led to 80,000 more people globally benefitting from reduced disability and better quality-of-life after acute stroke **[Lancet 2104; Lancet Neurology 2016a, b; Case Study B:Alteplase]**. Extending the methodological principles and know-how from large-scale stroke trials has led to innovation in pragmatic trials of repurposed medicines. **Chandran** found no benefit of three repurposed oral medicines for progressive MS in the MS-SMART multi-arm trial **[Lancet Neurology 2020]**. **Dennis** found no benefit of fluoxetine after stroke **[Lancet 2019]**. **C.Ritchie** leads an EU-Pharma consortium that has established the methodological and outcomes framework for early intervention multi-centre trials for dementia **[Alzheimers Dement 2017, PMID:28365321]**.

Our expertise in large-scale, multi-centre clinical trials has resulted in **Sandercock** chairing the independent Data Monitoring Committee of the RECOVERY trial, the world's largest randomised controlled trial of treatments for COVID-19, coordinated from the University of Oxford. This led to a change in intensive care treatment for COVID patients worldwide.

1.3.3.2 Neurodegeneration and repair

The relationship between synaptic pathology, neuronal loss and function remains understudied. Exploiting patient cohorts, accelerated brain tissue retrieval and state-of-the-art quantitative microscopy **Smith** showed that prefrontal cortical synapse loss is associated with cognitive decline in MND **[Acta Neuropath 2018]**. **Spires-Jones** showed region-specific depletion of synaptic mitochondria in Alzheimer's brains **[Acta Neuropath 2018]** and **Gillingwater** showed no loss of the neuromuscular synapse in patients with cancer cachexia **[J Clin Invest 2020]**.

Edinburgh Neuroscience hosts the £11M Department of Health National CJD Research and Surveillance Unit that anchors a range of prion-based research. Findings, including **Knight**'s development of a new diagnostic blood test for presymptomatic and symptomatic variant CJD **[Science Transl Med 2016]**, feed into public health policy-making. The group has demonstrated negligible transmission risk associated with specific areas of clinical blood use, which has resulted in a change in UK and Irish laws. This has dramatically increased the number of permitted blood donors and the availability of plasma and pooled platelets, with estimated savings to the NHS of £814M over a 50-year period **[Case Study J:vCJD surveillance]**. **Green** has extended her novel RT-QuIC assay for variant CJD diagnosis to alpha-synuclein detection to differentiate uncertain cases of Parkinsonism **[Ann Neurol 2016, 2019]**. **Manson** showed that misfolded prion protein alone is insufficient for neurodegeneration **[PLoS Biology 2016]**.

In addition to rodent models, Edinburgh Neuroscience has invested heavily in a suite of experimental systems including *C.elegans*, zebrafish, large animal and human iPSC platforms for discovery and screening (Section 3.4). **Doitsidou** identified a probiotic bacillus that protects against alpha-synuclein aggregation in *C.elegans* **[Cell Reports 2020]**. Using zebrafish, **Sieger** showed that neoplastic cells hijack endogenous neuron-microglial signalling pathways to promote proliferation **[eLife 2019]** and **Becker** found that Wnt signalling controls pro-regenerative Collagen XII in spinal cord regeneration **[Nat Commun 2017]**. **Lyons**, in collaboration with Biogen, used an *in vivo* zebrafish screen to identify novel chemical regulators of myelination **[eLife 2018]**. **Selvaraj** found *C9ORF72* mutation-dependent upregulation of GluA1 in patient iPSC-derived motor neurons **[Nat Commun 2018]** and **Chandran** also used a human platform to identify autophagy-inducing drugs that promote TDP43 turnover and cell survival **[Nat Chem Biol 2014]**.

Combining machine learning and artificial intelligence approaches with big data — pre-clinical and clinical — **Macleod** has championed structured and systematic analysis of existing research to reduce translational failure of laboratory studies and drive research improvement **[Lancet 2014; Case Study G:Rigour]**. **Pal** used the National MND Research and Care Cohort to define the genetic epidemiology of MND-associated variants in the Scottish population **[Neurobiol Aging 2017]**. **Muniz-Terrera** demonstrated the feasibility and benefit of conducting analysis across multiple international studies to show that education can delay cognitive decline in later life **[Alzheimers Dement 2018]**, and with **MacLullich** demonstrated at the population level that delirium adds independently and multiplicatively to the pathologic processes of classic dementia **[JAMA Psychiatry 2017]**. **MacLullich** has developed and evaluated the 4AT test for delirium, now the most-used clinical tool for delirium assessment in the NHS **[Case Study A:4AT Delirium Assessment Tool]**.

Abrahams and **Bak** devised and validated a new cognitive and behavioural tool for MND patients, the Edinburgh Cognitive ALS Screen (ECAS), which has been adopted internationally as the benchmark for evaluating cognition in MND **[Case Study C:ECAS]. Hunt** identified a new side-effect of interferon beta treatment in MS, thrombolytic microangiopathy (TMA) **[New Engl J Med 2014]**. This observation has led to a warning on the drug's safety sheet, and all patients taking high-dose interferon beta are now monitored for early-warning signs of TMA **[Case Study I:TMA]**.

1.4 Ethical Open Research

Edinburgh Neuroscience is committed to the highest ethical standards in the planning, conduct, analysis and dissemination of research. **Macleod** is the University's Academic Lead for Research Integrity and Improvement. Under the umbrella of the University Research Ethics and Integrity Review Group, Edinburgh Neuroscience assists researchers with the planning and implementation of methodologically robust, ethically approved research and driving improvements in research design, data management and publishing. Moreover, our extensive engagement with key stakeholders, especially patient bodies (Section 4), is a key element of our ethical, open and inclusive research strategy.

We are committed to helping researchers navigate the research regulatory landscape as well as the development and implementation of guidelines, such as ARRIVE 2.0 (animal research). For example **Calia**, E.Grant (UoA1) and colleagues developed a Global Research Ethics Toolkit designed to support researchers address the ethical challenges in global health contexts such as COVID-19.

Building on our experience of human clinical research **[Salman**, **Macleod**; **Lancet series on Research Waste, 2014, PMID:24411643],** Edinburgh Neuroscience is a leader in identifying priority areas for improvement in pre-clinical and in psychological research. **Pernet** contributed to the Open Science Collaboration: Psychological Science Reproducibility Project **[Science 2015]** and participates in the #EEGManyLabs Study. Under the editorship of **Della Sala**, *Cortex* became the first journal to establish 'Exploratory Reports' and 'Verification Reports' article types: novel publishing formats to advance Open Science. **Macleod** and Sena (UoA1) established CAMARADES, a collaborative group (six global national coordinating centres on three continents) pioneering meta-analysis and systematic review to assess reproducibility in pre-clinical studies. **Macleod** co-leads The UK Reproducibility Network, a peer-led consortium investigating robust research; **Macleod** and Sena's work has influenced major publishers, including Nature Publishing Group, to implement strict criteria for reporting study methods, funding bodies to examine

experimental design and pharmaceutical companies to define a shared quality management framework **[Case Study G:Rigour]**.

Edinburgh Neuroscience is committed to Open Science aiming to increase the proportion of (i) conducted research that is published, and (ii) published work that is open access. We have gone above and beyond the HEFCE Open Access policy since its implementation in April 2016: 95% (3886 of 4086) of the peer-reviewed articles published by our constituent Schools have been made compliant in our institutional repository, PURE.

Edinburgh Neuroscience supported the launch of the Edinburgh ReproducibiliTEA Open Science Journal Club, organised by two PhD students. This group meets monthly, with 70+ attendees, and has a monthly 'Open Research@EN' corner in our weekly News email (reach >1,500).

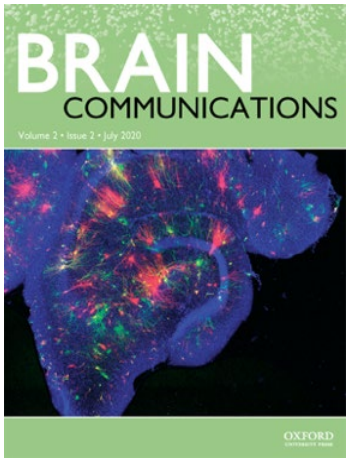

Fig. 1.6: *Cover of Brain Communications*

Two new fully open access journals have been launched under the inaugural editorships of **Spires-Jones** (*Brain Communications;* Fig. 1.6) and Sena (UoA1; *BMJ Open Science*). In 2016, **Spires-Jones** published findings from a survey of ECRs on the challenges of making publications and data open **[Eur J Neurosci 2016, PMID:26950407]**. **Rochefort** has co-developed two free, open-source software tools: FOCIA (Fast, Open, Cellular Imaging Analysis Toolbox) and FISSA (a neuropil decontamination toolbox for calcium imaging signals); **Luksys** co-created the COSMOS platform (COgnitive Science Metrics Online Survey) **[J Tech Behav Sci, 2018, doi.org/10.1007/s41347-018-0071-5]**, a free, online research tool for assessment of cognition.

1.5 Future Strategy

Our aim is to continue to grow excellence and impact in neuroscience, psychiatry and psychology with a focus on driving data-driven innovation and translational inter-disciplinary research across the life-course, and specifically:

1) To better understand and interrogate whole-body influences on brain health across the life-course, we will create a **Brain-Body Institute**. This will break down traditional barriers by coalescing into shared research space expertise in vascular science, metabolism and inflammation along with brain sciences so as to integrate the genetics, 'omics, imaging and clinical phenotyping skills of each discipline.

2) Edinburgh Neuroscience will capitalise on the opportunities offered by the £661M Edinburgh City Region Deal (2018), the vision of which is to make Edinburgh the data capital of the world, by working with data informatics expertise and the NHS-linked dataloch of the new Usher Institute building (£68M, opening 2023) to exploit big data collected across the life-course to examine the normal, ageing and diseased brain.

3) To address the mounting global burden of psychological ill-health in young people, we will establish a **Centre for Understanding Risk and Resilience** underlying psychiatric disorders. The Centre will leverage human population-based prospective longitudinal studies alongside

experimental research to create a centre of international excellence in data-driven biological psychiatry and global mental health.

4) To examine the individual, family and societal triggers and drivers of mental health and ill-health, we will establish a University-wide inter-disciplinary **Mental Health and Society Network** that integrates humanities and arts alongside clinical practitioners. The network will develop and implement new cross-cutting preventative strategies and influence policy more effectively.

5) To train and promote the entrepreneurial skills of our postgraduate students and ECRs, we will form an **Edinburgh Neuroscience Innovation Cluster**. An explicit focus will be growing new company formation, increasing patent filing and establishing strategic partnerships with industry.

2. People

2.1 Staffing strategy

Our staffing strategy is centred on recruiting, growing and retaining the best researchers, while addressing structural barriers to promote a diverse and inclusive environment.

We follow the key principles of the 'Concordat to Support the Career Development of Researchers' (UoE is a signatory) and have the following aims:

- To make new appointments that further an area of strategic importance and promote new collaborations, with a focus on expanding the ECR community

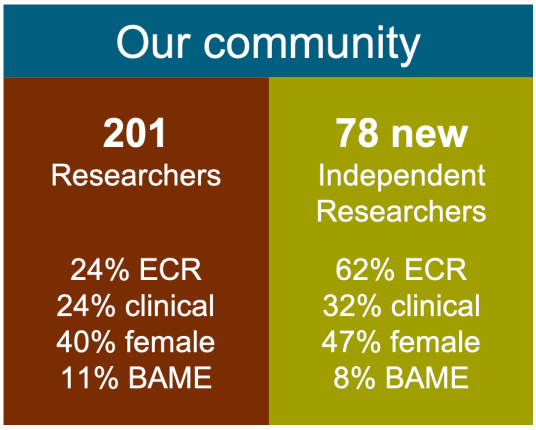

Fig. 2.1: *The make-up of our research community and our new researchers*

- To actively encourage diversity in all dimensions among new appointments and throughout our community
- To support academic staff at all career stages and encourage their development towards open-ended academic posts or along parallel career trajectories, recognising outreach, impact and other activities allied to the research in promotions panels
- To employ talented technical and professional services staff to underpin our aims, and to support these staff in their careers and personal development

2.2 Recruitments, promotions and career development

2.2.1 Independent researchers, including ECRs

The 201 researchers returned here (189FTE) represent a 56% increase since 2014 (129 were returned). Of this increase, 61 represent new recruitment to UoE, while the remaining 17 represent internal career progression (Fig. 2.1). 24% of our researchers are clinically active.

Fig. 2.2: *Internal career progression: ECR to Personal Chair in Developmental Psychology*

Overall, 27% of our researchers are at professorial level, including 12 new Personal Chairs. New recruitments were: **Crow** (neuroinflammation), **Priller** (innate immunity/psychiatry), **K.Ritchie** (cognition in pre-clinical dementia) and **Waldman** (structural and positron emission tomography [PET] imaging); eight were internal promotions (**Chin**, **Duguid**, **Fletcher-Watson**, **Hunt**, **Lyons**, **Mason**, **Nolan**, **Spires-Jones**). Career trajectories of two representative 'case studies' are illustrated in Figs. 2.2 and 2.3, both highlighting membership of multiple research hubs and external engagement activities that contributed to promotion, but reflecting different routes (internal promotion *versus* external fellowships).

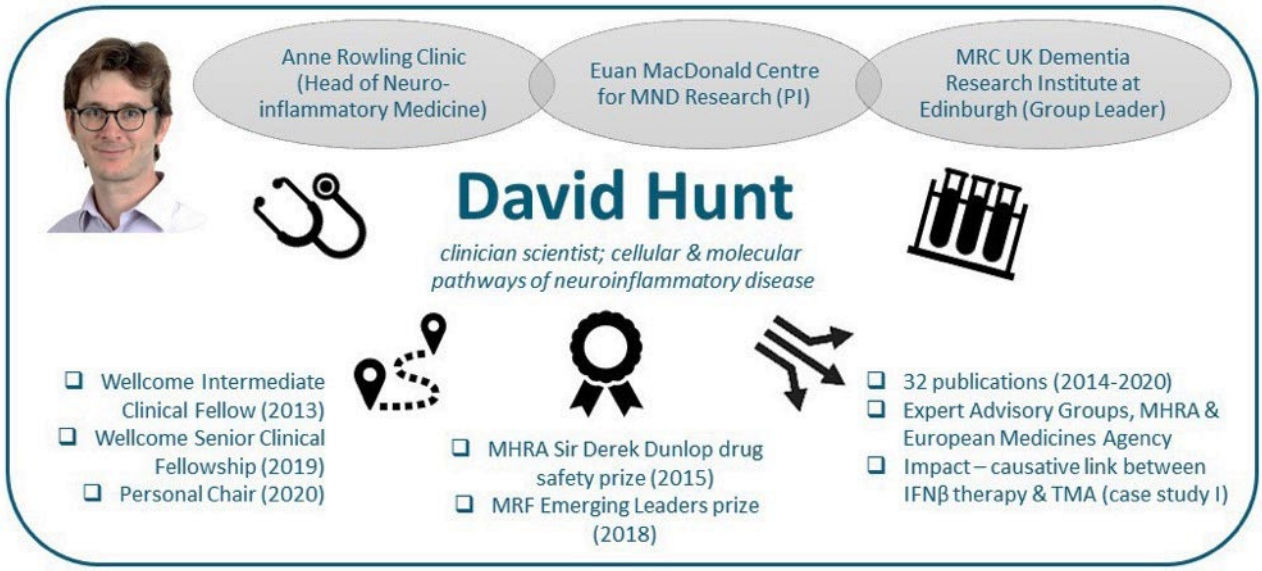

Fig. 2.3: *Career progression by fellowships: Clinical Fellow to Personal Chair in Neuroinflammation Medicine*

24% of our researchers are ECRs. Among the 29 Chancellor's Fellows and Edinburgh Scientific Academic track (ESAT) tenure-track scientists in REF2014, 14 have now transitioned to open-ended contracts at UoE, with six promoted to Reader (**Auyeung**, **Chan**, **Chevalier**, **Luciano**, **Mottus**, **Rabagliati**) and two to Professor (**Fletcher-Watson**, **Spires-Jones**). A further 16 tenure-track appointments have been made (50% female, 31% BAME). Five clinical academic ECRs are

on the Wellcome-funded Edinburgh Clinical Academic Track (ECAT) or Scottish Clinical Research Excellence Development Scheme (SCREDS) (**Fernandes**, **Gregory**, **Marwick**, **Romaniuk**, **Woodfield**), which provide an integrated training and career development pathway to facilitate a senior clinical academic appointment and a clinical Certificate of Completion of Training.

Some ECRs have achieved prominent PI roles within our research hubs: **Spires-Jones** is a Group Leader in the MRC UK DRI at Edinburgh, **Osterweil** and **Rochefort** are leads in the Simons Initiative for the Developing Brain and **Fletcher-Watson** leads the Salvesen Mindroom Research Centre.

Since 2014, our researchers have been awarded 32 external fellowships (31% to ECRs, 22% to clinical, 34% to female, 22% to BAME researchers). Non-clinical fellowships include eight Wellcome Investigator/Senior Fellowship (**Brophy**, **Cousin**, **Duguid**, **ffrench-Constant**, **Lyons**, **R.Morris**, **Nolan**, **Osterweil**), four Wellcome Sir Henry Dale Fellowships (**Gkogkas**, **Osterweil**, **Rochefort**, **Surmeli**), four from major charities such as Alzheimer's Research UK or Stroke Association (**Durrant**, **Fowler**, **Wang**, **Wiseman**), a British Academy Leverhulme Senior Research Fellowship (**Branigan**) and a British Academy Newton Advanced Fellowship (**Rabigliata**). Clinical fellowships include a Wellcome Senior Clinical Fellowship (**Hunt**), two Chief Scientist Office Senior Clinical Fellowships (**Mahad**, **Whiteley**), a Stroke Association Senior Clinical Lectureship (**Mair**) and a Wellcome Clinical Research Training Fellowship (**Breen**).

2.2.2 Postdoctoral researchers

In July 2020, we had 177 non-independent postdocs within Edinburgh Neuroscience. A further 17 transitioned to independent status during REF period, remaining at UoE, including **Hampton** (who started our online MSc in Stem Cells and Translational Neurology), **Marwick** (who was a PsySTAR PhD student and is now a SCREDS Clinical Lecturer alongside **Gregory** and **Romaniuk**), **Rooney** (who holds a Royal College of Physicians Edinburgh Sim Fellowship) and **Selvaraj** who was appointed Chancellor's Fellow.

2.2.3 Professional services staff

Since 2014 we have substantially enhanced and broadened our senior professional services staff and now have a team of 12.3FTE to support strategy, impact, commercialisation, communications and public engagement. We have increased the Edinburgh Neuroscience Scientific Coordinator role and employed an Assistant. Other new posts include: Science Manager to oversee strategy, recording and reporting; two Impact Officers to promote an impact culture and guide our researchers in achieving impact; a Business Development Executive who supports industry engagement and commercialisation; a Knowledge Exchange Manager and a Communications Manager.

We often partner professional services teams with an academic lead to bring a different perspective: positions include Data and Open Research Director (**Macleod**) and Academic Lead for Public Engagement (**Rhodes**).

2.2.4 Postgraduate students

The number of doctoral degrees awarded this REF period has increased to an average of 49.5 per year (38.4 in REF2014) and, in a major change, since 2019 our flagship PhD programmes have been able to offer full funding for overseas students (including low-and-middle-income countries).

We have created two new fully funded PhD programmes led from Edinburgh Neuroscience, including one with UoE's new 4-year 'PhD with integrated study' model:

- Wellcome 4-year **PhD Programme in Translational Neuroscience** (Director: **ffrench-Constant** then **Lawrie**): 24 basic science students (4 intakes, 2016–2019; £4.5M, £1M from UoE) plus successful renewal for an additional 30 students (5 intakes 2020–2024; £6.4M, £1M from UoE)
- Chief Scientist Office (Scottish Government) **SPRINT-MND/MS PhD Programme** (Director: **Chandran**): pan-Scotland, involving five University partners: Aberdeen, Dundee, Edinburgh, Glasgow, St Andrews (12 students, 3 intakes, 2017–2019; £0.45M)

Our researchers actively contribute to four other flagship programmes:

- MRC Precision Medicine: 23 students awarded to UoA4 researchers in REF period
- Advanced Care Research Centre PhD Academy: 12 students per year, 6 UoA4 supervisors in pool (new in 2020)
- Wellcome-funded ECAT programme: 9 students awarded to UoA4 researchers
- BBSRC-funded EASTBIO programme:16 students awarded to UoA4 researchers

In addition, our Schools and research hubs offer PhD and doctorate schemes:

- Simons Foundation-funded Simons Initiative for the Developing Brain (new; 28 students, £2M, 2018–2026); Euan MacDonald Centre for MND Research (10 students, £750K); Rowling Scholars clinician-scientist PhD scheme (new; 7 students, £600K)
- PhD in Psychology (17 students per year, £940K) and Clinical Psychology (11 per year, £360K)
- NHS Education for Scotland-funded three-year Doctorate in Clinical Psychology (42 per year)

We have expanded our **postgraduate taught portfolio** with a new online Masters in Stem Cells and Translational Neurology (Directors: **Hampton**, **Chandran**; 12 students a year). This complements our on-campus Masters by Research in Integrative Neuroscience (Director: **Becker**) which has seen a 62% increase in enrolment since REF2014 (now capped at 42 students a year), our MSc in Applied Psychology for Children and Young People (30 students per year) and five Psychology-themed MSc programmes (70 students per year).

2.3 Supporting our staff

2.3.1 Support for career development

Edinburgh Neuroscience staff have access to an extensive suite of career and personal development opportunities, and support provided by UoE (Sections 2.3.3, 3.2 and REF5a, 3a,b).

All staff (including postdocs, technicians and professional services) have a mandatory Performance and Development Review annually, which provides an opportunity for both staff member and line manager to reflect on achievements, training and career development aspirations.

A one-stop-shop for staff and students' training and career development is provided by the UoE Institute of Academic Development (IAD). A comprehensive portfolio of free courses and workshops, mapped against the UK's Researcher Development Framework, allows staff to evaluate their current skillset and plan their personal development. Additionally, IAD staff offer one-to-one consultations with a professional careers advisor.

Academic staff with >3 years' service can request sabbatical leave on full pay, relieving them of administrative and teaching duties and providing space for further developing their research (33 have taken this opportunity).

The staff Mentoring Connections programme provides a platform for all staff to seek support and motivation over an extended period. Local Mentoring Champions advocate and promote mentoring as a positive development tool.

In response to the COVID-19 pandemic UoE has supported staff with home-working and caring responsibilities, including flexible working hours and University-wide respite days. Extensive measures were implemented to enable researchers to return to laboratories as soon as permitted. The disproportionate career impact on fixed-term staff was recognised: formalised ways to quantify disruption were implemented and ECRs, postdocs and final-year postgraduates were given priority in terms of access to labs and facilities, technical support and seedcorn funding.

2.3.2 Support for funding and impact

Edinburgh Neuroscience, in conjunction with Edinburgh Research Office and Edinburgh Innovations, prides itself on providing start-to-finish grant and fellowship support. This starts with collating relevant opportunities, providing funder intelligence and analysis of previous success rates, moves to help with costings and bid preparation to internal senior peer review to extensive interview preparation and mock interviews. Unsuccessful applications are discussed with a senior colleague and redirected/shaped where appropriate.

Focussed support at career transition points is particularly beneficial, so provision of opportunities has been a strategic priority. UoE and Edinburgh Neuroscience provide a portfolio of seedcorn funding schemes targeted at different career stages (Section 3.2), which prioritise securing pilot data to support substantive grant and fellowship applications and developing impact. Of the awards made in the RS Macdonald scheme, 43% were to female researchers and 37% to ECRs/postdocs, while 60% of Neuroresearchers Fund awardees were female (scheme is for ECRs). Finally, 30% of the RS Macdonald fund is reserved for postdoctoral applicants.

2.3.3 Training

In conjunction with the UoE IAD, Information Services and Research Data Services we offer a full spectrum of training opportunities in research and related transferable skills.

Skills-based initiatives include:

Management and supervisory skills: UoE offers three levels of leadership and management programmes to cater for aspiring, established and senior leaders; PIs are required to attend the 1-day workshop 'Managing your Research Group', which focusses on the people-management aspects of the role. PhD supervisors must complete initial training, including mental health first-aid training, and must refresh it every 5 years. ECRs and senior postdocs are included as assistant supervisors on our PhD programmes, where they are paired with experienced supervisors and

receive bespoke training. Postdocs and ECRs are actively encouraged and supported to supervise short duration (10 week–6 month) research projects undertaken by BSc and MSc students.

Commercialisation and industry engagement: Our community has a dedicated Business Development Executive for Neuroscience, who provides specialised advice and contacts for developing partnerships with industry and venture capital, plus assistance with patent-filing, new company formation and consultancy. Since 2017, nine researchers have held partnerships worth £9M with 13 industrial companies (63% increase on REF2014) while 51 (33% female, 8% BAME) have held 358 consultancies with 120 companies, worth £3.6M.

Patient and public engagement: The Edinburgh Neuroscience Scientific Coordinator, with the Edinburgh Neuroscience Academic Lead for Public Engagement (**Rhodes**), UoE Public Engagement with Research Manager and College Communications team, collates and promotes public engagement opportunities and works with researchers to devise, conduct and evaluate activities, in alignment with UoE strategy (See REF5a 2e).

Fig. 2.4: *Euan MacDonald Centre PhD students talk to a local football team about their work*

We have strong connections with patient groups (Section 4.1.4). Many of our non-clinical students and postdocs will have never met people living with the particular condition they are researching; we therefore invite students to sit in on clinics and listen to patients at focus groups. They are encouraged to take part in Open Evenings (e.g. twice-yearly at the Anne Rowling Clinic), small-group patient:scientist exchanges, present their work at patient support groups, and devise creative ways to enthuse the public about their research to community fundraisers and at science festivals (Fig. 2.4).

International experience: The Centre for Developmental Synaptopathies at InStem, Bangalore (Associate Directors: **Chandran, Kind**), provided opportunities for PhD students and postdocs to work alongside researchers from this jointly managed centre. Seven students have each spent >6 months in India, alongside four postdocs from Edinburgh who established research techniques there. Complementing this, 17 Indian PhD students and postdocs have spent time in Edinburgh. Our partnership with Brain Centre Rudolf Magnus has funded 30 PhD students to visit Utrecht for workshops and lab visits.

Other initiatives are aimed at particular career stages:

Postdoctoral support: Postdoc societies provide networking / peer-support and training (grant writing, publishing, engagement and career paths) and educational retreats at the UoE Firbush field station in the Highlands. We promote postdoc 'visibility' through individual web profiles, external communications and leadership roles in the research hubs, such as co-I status or managing events and chairing academic sessions.

Postgraduate support: Students benefit from dedicated Postgraduate Administrators to oversee progression and provide pastoral support, plus a PhD Thesis Committee, which meets at

least annually and is chaired by an academic unrelated to the research project. PhD students are encouraged to present their work at scientific meetings (e.g. Neuroscience Day, Scottish Neuroscience Group, School-level and research hub meetings and Away Days) as well as participate in the University '3-minute thesis' competitions (in 2018, student Owen James won the UK final with his one-slide talk 'Human Myelin in a Dish'). Students are encouraged to undertake paid undergraduate demonstrating and tutoring up to 9 hours a week, and to apply for postgraduate teaching contracts.

To prepare for life post-PhD, we have developed a portfolio of activities that not only look at academic careers but also explore other career paths, e.g. our annual Autumn School for PhD students, 'Beyond a PhD' webinar series, talks by alumni and transferable skills workshops. Four students have undertaken paid internships with the Scottish or UK Government, contributing to policy research (Fig. 2.5) and the 'Violence in the Scottish Crime and Justice Survey'. The Wellcome-funded PhD programmes now provide post-PhD transition funding, whose contributions UoE has matched.


UK Parliament POST

POSTNOTE
Number 612 January 2020

Autism

Autism affects the way that someone engages with the world around them. A cross-government adult autism strategy, *Think Autism*, was published in 2014. This note provides an overview of policy issues that are relevant to autistic people and their families.

Overview
- Autism affects at least 1% of the population, although it is likely that this is under-estimated, particularly in non-males.
- Autism frequently co-occurs with other conditions, including mental health conditions, learning disability, and epilepsy.
- A range of interventions are available for autistic people, which include treatment of co-occurring conditions, support with communication, and providing support for parents and families.
- The Autism Act (2009) and relevant strategies have increased autism awareness, but autistic people continue to be disadvantaged in areas including health outcomes, education, employment, and the criminal justice system.

Fig 2.5: *A PhD student's internship resulted in her writing a 'POSTNOTE' on Autism for the UK Parliament*

Technician and facilities support: Technical expertise and facilities are vital for our research programmes. UoE has instigated initiatives to provide support and career development for technicians (REF5a, 3d), including a newsletter with special issues related to COVID-19 planning. The Core Facility Staff Network, initiated in July 2018, comprises managers from the 26 College core facilities, technicians, technologists, researchers and administrators. Its intentions are to share best practice and promote the four pillars of the Technician Commitment (career development, recognition, visibility, sustainability). Among its achievements, the network has published a 'fair publication policy' (2020) to recognise the contribution of technicians in authorship lists, which Edinburgh Neuroscience has adopted (e.g. see Fig. 1.2), and facilitated professional registration of 10 staff.

2.3.4 Communities

A cornerstone of the Edinburgh Neuroscience philosophy is that we are — from final year undergraduates to Professors, and across research themes — a single community.

This strong sense of community is anchored in our cross-disciplinary approach to research (32% of outputs submitted are inter-disciplinary), and reinforced by our bespoke website (average 90K hits a year), weekly email digests (distributed to >1,500 people) covering everything including successes, funding opportunities, jobs and events.

Collaboration is fostered via our cross-community training activities, our PhD programme retreats at the Firbush field station (Fig. 2.6) and our annual 'Neuroscience Day' networking event (c.300 attendees, 70 posters, talks across all career stages, plus external Annual Distinguished Lecture) following which 29% of attendees report starting new collaborations (Section 4.1.1).

***Fig. 2.6**: Translational Neuroscience PhD student retreat at Firbush*

2.4 Supporting Equality and Diversity

UoE and Edinburgh Neuroscience are committed to promoting equality and diversity. Our community is both global and diverse and this enrichment has increased since REF2014. The 201 researchers returned here:

- Come from 25 different countries with 34% non-UK, an increase that has been maintained from REF2014 (RAE2008 12%, REF2014 29%)
- Are 40% female, a consistent increase on both RAE2008 (29%) and REF2014 (32%). Of our Professors, 20.4% are female (up from 17.5% in REF2014)
- 11% identify as BAME and this includes Professors, senior researchers and ECRs
- 32% are under 40 years of age and 33% over 50

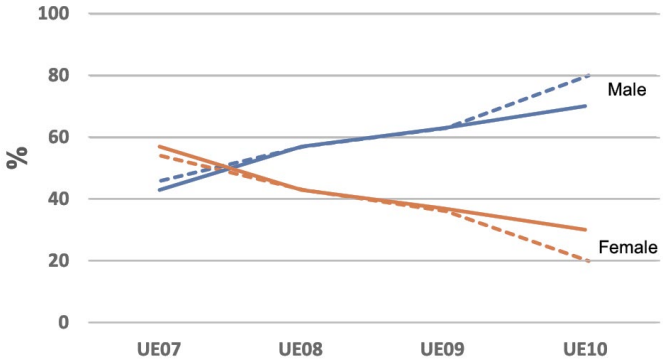

***Fig. 2.7**: Grade and gender profile of researchers (solid line) and REF2 outputs (dashed). Blue = male; red = female*

Our submitted REF2s reflect the researchers in this return by both gender and career stage, with good agreement at almost all career grades (Fig. 2.7). Initial selection of REF2s was undertaken by an algorithm that was blind to gender and career stage. We then performed manual checks of all associated authors on outputs being submitted, affording the opportunity to make substitutions to ensure our REF2 submission closely reflects our researcher pool.

2.4.1 Recruitment and career progression

Our recruitment process addresses the structural barriers affecting people of different ethnicities and genders. Of our 78 new academic researchers, 47% are female, 32% clinically active and 8% BAME (Fig. 2.1). Of these, four were professorial appointments (25% female, up from 11% in REF2014), while 50% (9 of 18) of those who made a successful transition from ESAT Fellows to open-ended substantive posts (Senior Lecturer or above) by July 2020 are female, e.g. **Spires-Jones**, **Fletcher-Watson**, **Wang**, **Whalley**.

Four female colleagues have risen to senior leadership positions: **Spires-Jones** is Deputy-Director of the largest organisational grouping in this return, managing 74 PIs; **Wardlaw** is Head of Edinburgh Imaging; **Fletcher-Watson** is Director of the Salvesen Mindroom Research Centre; **Branigan** is Head of the School of Philosophy, Psychology and Language Sciences.

2.4.2 Representation and visibility of diverse role models

Measures we have taken include:

- The Edinburgh Neuroscience Board consists of 13 senior staff, of whom 38% are female and 23% BAME
- Our seedcorn-funding committees (Henderson Scholarship, Neuroresearchers Fund, RS Macdonald Seedcorn Fund) are 50%, 30% and 50% female respectively, with the latter two comprising 13% and 30% BAME members, respectively
- Since 2014, female and BAME representation amongst internal speakers at our flagship annual Neuroscience Day meeting (c.300 attendees) has increased to 42% and 15% respectively (from 29% and 7% in REF2014). 57% of our Annual Distinguished Lecturers have been female and 29% BAME (compared with 16% and 0% in REF2014). In 2016 we introduced a PhD student session to ensure that researchers at every level are included in our programme (61% female, 13% BAME)
- Across all seminar series in this return (>300 speakers), the percentage of female speakers has risen from <30% in 2014 to 48% in 2020, and BAME speakers from 2% to 33%

2.4.3 Active promotion of equality, diversity and inclusivity

UoE is committed to creating and promoting a positive culture that celebrates diversity, challenges prejudice and ensures fairness; this is evidenced by the widespread take-up of 'rainbow lanyards', instigated in 2017. It has put in place a portfolio of policies and initiatives, including holding an Institutional Athena SWAN Silver Award, and establishing the Equality, Diversity and Inclusion Committee to implement its Equality and Diversity Strategy (see REF5a 3e). The University has an active Staffpride Network, which was named Stonewall Scotland's Network Group of the Year (2018) in recognition of its efforts to promote an inclusive and supportive culture for LGBT+ colleagues. **Spires-Jones** has undertaken Stonewall Allies training.

Edinburgh Neuroscience initiatives include:

- We have held Athena SWAN awards since 2008: currently two Silver (Clinical Psychology, 2017; Edinburgh Clinical Medical School, 2016) and two Bronze (Biomedical Sciences and Psychology, both 2017)
- To help enable a successful work-life balance, UoE staff have the right to request flexible working including working at home (REF5a 3a). Currently, 14% of Edinburgh Neuroscience researchers work part-time, and 78% have open-ended contracts. To support these staff, we have offered workshops on 'Understanding the challenges of part-time researchers' and a one-day conference addressing 'Part time research; full time challenge'
- Parental and adoption leave now includes 'keeping in touch days' and a Returners' programme for staff who have taken leave greater than 4 months, providing 6 months protection from teaching upon return. During this REF period 42 of our staff have taken partner/parental leave.

- Equality & Diversity and Unconscious Bias training is compulsory for all staff in neuroscience. AdvanceHE's Diversifying Leadership programme is designed to support early-career academics and professional services staff from BAME backgrounds who are about to take their first steps into a leadership role
- The University has a zero-tolerance stance towards any form of bullying: the 2019 'Don't Cross the Line' campaign and workshops raised awareness to reduce all forms of bullying and harassment. All staff have access to a Dignity and Respect advisor, and the 'Respect at Edinburgh' web hub is a resource for staff and students. Staff are encouraged to become Respect Champions for their work area.

Diversity@EN

In Spring 2019 we established 'Diversity at Edinburgh Neuroscience', a grouping from all career levels representing a wide range of diversity (including wheelchair users, people with hidden disabilities, hearing and speech challenges, autism, ethnic and social background diversity). This group provides guidance to the Director (**Chandran**) and Board. The group has already instigated many positive changes:

- Changed the registration process for Neuroscience Day to better accommodate those with hidden disabilities or special requirements and provided a prayer room at one-day meetings
- Prompted the Board to conduct a survey seeking information and suggestions on issues related to ethnicity and religious identity. These issues are now a standing item on the Board agenda
- Issued a statement in support of Black Lives Matter calling on UoE senior management to initiate specific changes. The social media reach was 22K and the website-hosted statement has been read 711 times
- Organised 'Diversity Drop-in' sessions every month that are open to anyone
- Established Diversity@EN communications: webpage, Twitter feed (reach 34K since July 2020) and resource Wiki, plus Diversity Corner: a monthly section in the Edinburgh Neuroscience news email to highlight issues, resources and personal experiences

Research community feedback includes: "Diversity EN is a great start", "Really proud of EN for putting out this statement", "Thank you for taking an interest and showing a desire to effect change".

Section 3. Income, infrastructure and facilities

3.1 Research funding

Edinburgh Neuroscience has received £257M in strategic awards (Fig. 3.1 for examples), including £135M to our research hubs, £11M to maintain our National CJD Research and Surveillance Unit, £11.4M for our PhD programmes and £39.3M for our overseas partnerships. In addition, £27M has been awarded in 32 Fellowships plus £4.2M for three ERC research awards (Start-up, Consolidator and Advanced), £7.5M Dementias Platform UK awards and £9.9M investment in the Generation Scotland and Generation Malawi cohorts. We have also received £9M in translational and industrial funding plus £3.6M from consultancies with 120 companies.

Totalling £257M, this represents a 2.5-fold increase on £103M, the closest equivalent value in REF2014.

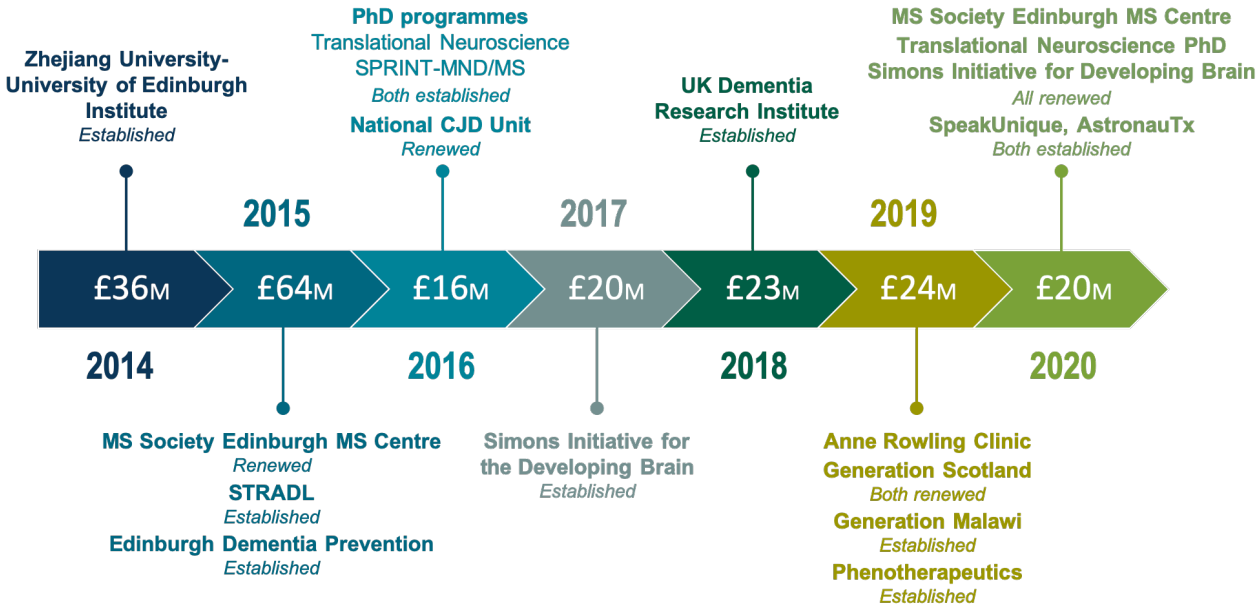

Fig. 3.1: *Exemplar large and strategic awards and developments*

Strategic funding won by Edinburgh Neuroscience has transformed the research environment since REF2014. Two awards totalling £32M by the Simons Foundation have created the Simons Institute for the Developing Brain (**Kind**). The award of a UK DRI Institute to Edinburgh with an initial £23M investment (**Hardingham**, **Chandran**, **Wardlaw**), along with the £50M European Prevention of Alzheimer's Disease Consortium (**C.Ritchie**) unifies our research into ageing, neurodegeneration and dementias. The two renewals of our MS Society Edinburgh Centre for MS Research, with awards of £2M and £1.9M in 2015 and 2020, respectively (**Chandran, ffrench-Constant**), have enabled us to continue our expansion, bringing together myelin biology, neuroinflammation and neuroimaging, while an additional £15M philanthropic investment into the Anne Rowling Regenerative Neurology Clinic (**Chandran)** ensures the prioritisation of human-centred research. The £11M renewal of the National CJD Research and Surveillance Unit (**Smith** and **Knight**) maintains this nationally important resource for understanding neurodegenerative prion diseases, while the £10.9M award/renewal of the Wellcome-funded Translational Neuroscience PhD programme (**ffrench-Constant**, **Lawrie**) has created an ambitious programme training basic neuroscientists in a deep understanding of clinical brain disorders.

3.2 Strategies to generate research income

We have four key strategies to enhance research income and leverage impact:

- Nucleation of our research around externally funded research hubs
- Actively soliciting philanthropy and community fundraising
- Providing seedcorn funding as a springboard to future substantive funding
- Providing bespoke end-to-end support for research and translation funding applications (Section 2.3.2)

As discussed earlier, our research hubs provide an enabling, collaborative and highly supportive environment that sparks inter-disciplinary collaboration and innovation. In turn, this grows income from fellowships, project and programme grants. As an example, the £1M initial donation to found the Euan MacDonald Centre in 2007 has since leveraged over £20M in MND-related research grants. We engage with philanthropists through UoE Development and Alumni and have received or been pledged £64M in donations since 2014; our students and postdocs often conduct lab tours for donors (including author J.K. Rowling and rugby legend Doddie Weir).

Seedcorn funding enables new collaboration, translation and impact, transition to fellowship support and/or obtaining pilot data in new research areas. In partnership with Edinburgh Research Office and Edinburgh Innovations, we have created a portfolio of seedcorn funding options to ensure maximum eligibility:

- **UoE Chancellor's Fellow and ESAT schemes** provide starter funding and PhD studentships to ECRs (£100K per fellow)
- **RS Macdonald Trust Seedcorn Fund**: This fund promotes new collaborations. Sixty awards (£229K) have been made (43% to female researchers, 36% to ECRs/postdocs), leveraging £2.1M further funding (7-fold return), including a Wellcome Sir Henry Dale Fellowship to **Gulsen** and a £0.6M MRC grant to **Smith** to support the small vessel disease brain bank
- **Arts Humanities and Social Sciences Development Award** is for mid-career researchers. With School-specific pilot schemes it has awarded £155K to Edinburgh Neuroscience researchers and led to grant awards totalling £2.1M (13-fold return), including three ESRC Future Leaders (**Rabagliati**, **Stanton**) and a Leverhulme Senior Fellow (**Branigan**)
- **Research hub-specific initiatives:** For example, the Simons Initiative for the Developing Brain offers seedcorn funding (£10M over 8 years) and studentships. The Anne Rowling Clinic has awarded £80K in career-bridging funding, plus many 1-year fellowships for clinicians and graduate internships
- **Neuroresearchers Fund** is available to PhD students, postdocs and non-tenured staff to visit labs for training and new collaborations. The £27K awarded to 35 researchers in this REF period has leveraged £250K in fellowships and grants (10-fold return)
- **Henderson Scholarship** supports undergraduate summer research placements, including funding the host lab. This low-cost support is particularly beneficial to ECRs; £49K awarded to 19 students

Schemes specifically to foster translation and impact:

- **Institutional Strategic Support Fund**: Comprising £5M Wellcome and £3.75M UoE funding, this supports early-career researchers, translation, public engagement and other strategic challenges. In REF period, 24 Edinburgh Neuroscience researchers were awarded £838K (58% to ECRs, which leveraged £24M in further grant funding (28-fold return), notably the UK DRI at Edinburgh (**Hardingham**), an ERC Consolidator award (**Rochefort**) and a Wellcome Henry Dale Fellowship (**Gkogkas**)
- **Wellcome Translational Partnership Award**: This £1.3M award funds early steps to translation; two entrepreneurs-in-residence work with the ECRs. Edinburgh Neuroscience

researchers have been awarded £61K, with five projects currently being developed for applications to UKRI or industry sources

- **MRC Confidence in Concept:** Also for translational development, £200K has been awarded to Edinburgh Neuroscience researchers, leveraging a further £1.8M from the Chief Scientist Office, Brain Research UK and EPSRC, plus forging links with Novartis, Dementia Discovery Fund, NRG Therapeutics, Autifony Therapeutics and NHS Scotland

3.3 Infrastructure

Three levels of infrastructure enable the research portfolio of Edinburgh Neuroscience: organisational (administrative structure), operational (buildings and campuses) and scholarly (cohort resources).

3.3.1 Organisational infrastructure

Centres/Schools: The Centre for Clinical Brain Sciences, Centre for Discovery Brain Sciences, School of Philosophy, Psychology & Language Sciences, and Clinical Psychology at the School of Health in Social Science provide an administrative home for staff and day-to-day finance and HR support. They unite researchers working around broad themes such as neurodegeneration, neurodevelopment or psychology. Each is directed by a senior academic, supported by a small team comprising administrative, financial, knowledge exchange and technical experts. Centres and Schools are responsible for grant application and awards, recording and reporting, staff development and student progression. Within each Centre/School there is a strong culture of promoting career advancement, encouraging grant application and success, with journal clubs, lab meetings, annual appraisals, mentorship, internal/external seminar series and social events.

Edinburgh Neuroscience forms an umbrella to enhance the research environment and opportunities for individual development. It has a Director (**Chandran**), an Executive Board (13 permanent academic members; 38% female, 23% BAME) from across all four Centres/Schools, and employs a dedicated full-time Scientific Coordinator (Haley) and Assistant. Unburdened by day-to-day administrative issues, Edinburgh Neuroscience has the freedom and flexibility to bring the community together through communications and PhD programme coordination, and enhance the research environment and its impact through training, knowledge exchange and events; driving cross-College initiatives; facilitating new discussion forums, such as a Brain Epidemiology Group and ReproducibiliTEA; arranging training/networking activities, e.g. 'Autumn School' for first and third-year PhD students, annual Neuroscience Day and monthly socials for the community.

UoE Edinburgh Research Office has been 'rebooted' and dramatically improved since 2014, providing end-to-end support for grant applications, contracts and awards, with a dedicated team for Edinburgh Neuroscience. In addition to costing, staff provide expertise and advice on framing knowledge exchange and data management resources within applications, as well as formalising partnerships and necessary legal arrangements. For fellowship applications they provide career development advice and oversee mock interviews. The Research Grants arm is responsible for financial management and post-award administration.

UoE Edinburgh Innovations representing translation, commercialisation and impact, has also been transformed in this REF period. The Business Development Officer for Edinburgh Neuroscience works with individual investigators to develop opportunities ranging from seedcorn funding through IP generation to spin-out formation (successes described in Section 4). They also

handle consultancy, another area of Edinburgh Neuroscience success: £3.6M from consultancies between 120 organisations and 51 researchers (33% female, 8% BAME). In 2020, they organised the 'Horizons in Neuroscience' meeting that brought together Edinburgh Neuroscience academics with representatives from industrial and venture capital firms (comprising 25% of attendees).

3.3.2 Operational infrastructure

Edinburgh Neuroscience is located on three campuses: one in central Edinburgh and the other two south of the city centre at hospital sites. Importantly, each site houses researchers from all three of our life-course research themes, promoting interaction and cross-disciplinary working.

Psychologists and the majority of our developmental neuroscientists, including those working on autism-related disorders, are located at the George Square campus in the city centre, housing 108 researchers in four buildings with >22K m^2 space (Fig. 3.2).

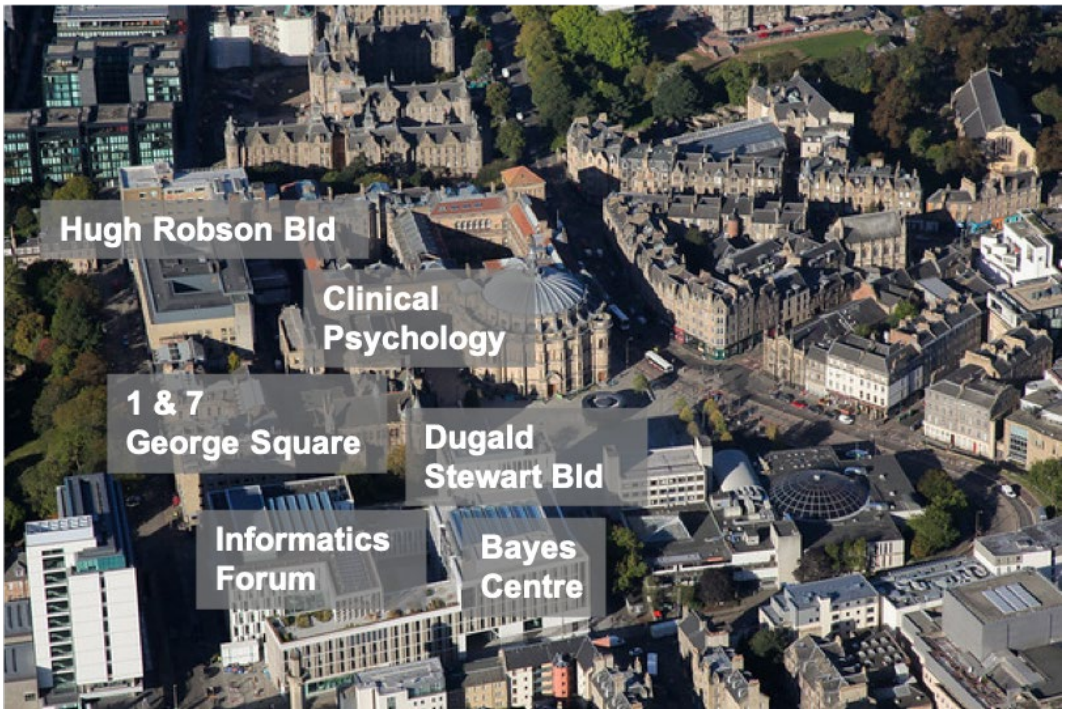

***Fig 3.2**: Edinburgh Neuroscience campus George Square. Our researchers are housed in 1 and 7 George Square, the Hugh Robson and Dugald Stewart buildings.*

Here, researchers are adjacent to the data scientists of the Informatics Forum and the £40M Bayes Centre that nucleates mathematical and physical scientists. This juxtaposition of psychologists, fundamental neuroscientists and informaticians has been instrumental in driving progress at the interface, and in analysis of the very large datasets generated by our population cohorts detailed below.

The remainder of our neuroscience community is located adjacent to two teaching hospitals in which many of the clinical academics also work. Psychiatrists, imaging and data scientists, and some psychologists, are located at the 3K m^2 Kennedy Tower on the Royal Edinburgh (psychiatric) Hospital site (including the clinical arm of the Patrick Wild Centre, Clinical Lead: **Stanfield**). Here 38 researchers and staff undertake translational research into major psychiatric conditions.

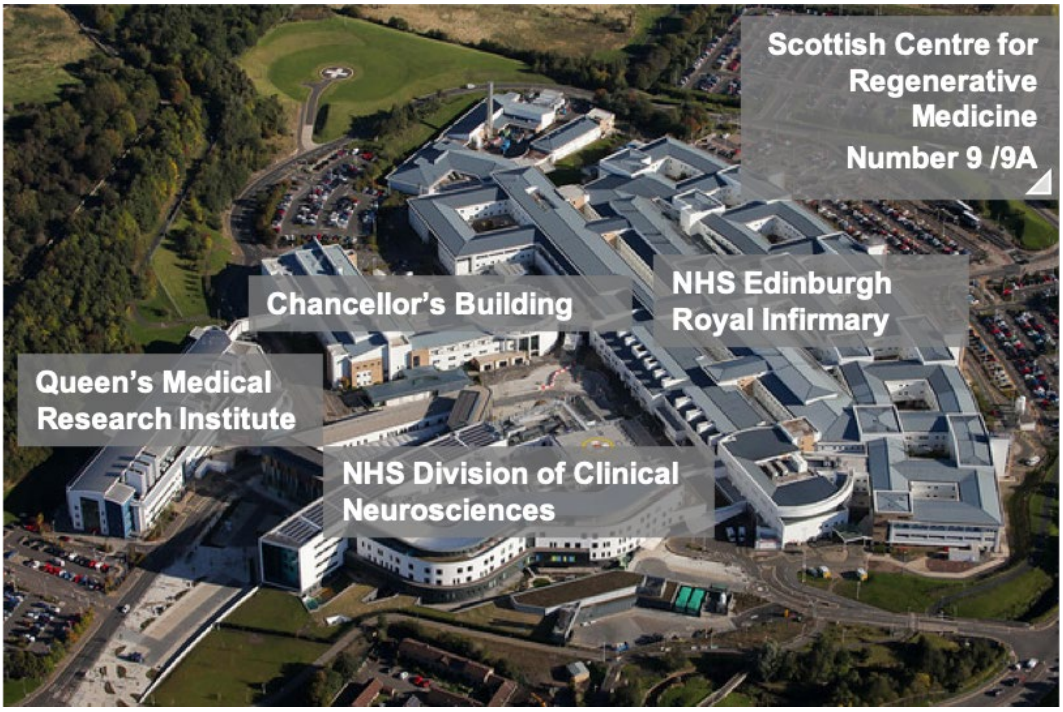

***Fig. 3.3**: Edinburgh Neuroscience campus Edinburgh BioQuarter*

Our clinical academics and neuroscientists focussed on neurodegeneration and neuroregeneration are located at **Edinburgh BioQuarter** (EBQ), a flagship investment in Scotland's life-science industrial strategy. Four large University buildings house Edinburgh Neuroscience researchers (Fig. 3.3): Chancellor's Building incorporating the Anne Rowling Regenerative Neurology Clinic, the Queen's Medical Research Institute, the Scottish Centre for Regenerative Medicine and Number 9 / 9A, housing the Usher Institute and Edinburgh Dementia Prevention, respectively. The 160-acre EBQ site creates a genuinely translational environment, also housing over 25 start-ups and life science companies, the University's Medical School as well as Edinburgh's largest teaching hospital, the 1000-bed Royal Infirmary of Edinburgh and the brand new (2020) £150M Royal Hospital for Children and Young People and Department of Clinical Neurosciences. The latter relocated all clinical neurology facilities and staff to a single site adjacent to our research community, creating the considerable added value and resources required for translation.

Chancellor's Building houses 60 of our researchers (and their staff) in a 20K m^2 space, including the £23M UK DRI at Edinburgh in newly refurbished facilities, and the £3.5M MRC Edinburgh Brain Bank. The building provides laboratories and offices for basic, translational and clinical research as well as for professional services support.

Fig. 3.4: *The Anne Rowling Regenerative Neurology Clinic provides a state-of-the-art and welcoming environment for clinical research*

A key translational resource is the Anne Rowling Regenerative Neurology Clinic (Fig. 3.4), which provides clinical research facilities essential for early translational studies and cohort-based research focussed on neurodegeneration and neuroregeneration. It has welcomed approximately 42K patients and research participants since it opened in 2013. It currently provides a 450m^2 space for 18 researchers, and will be expanded to include enhanced clinical research and trials capacity with a further philanthropic donation of £15.3M.

The regenerative neuroscience community, which includes groups working on myelin and MS, funded by two successive c.£2M Centre of Excellence awards from the Multiple Sclerosis Society, is located within the Institute for Regeneration and Repair. This Institute is focussed around the £50M Scottish Centre for Regenerative Medicine (opened in 2012) and the adjacent £45M Centre for Tissue Repair (due to open in 2021), and brings together scientists working in different tissues including the brain.

The Queen's Medical Research Institute (22K m^2 space) will become home to the fundamental neuroscientists currently located at George Square in 2024, when their location will unite them with the neuroscience community and the British Heart Foundation Centre for Cardiovascular Sciences (a BHF Centre of Excellence housing 200 researchers and staff) to create a new Brain-Body Institute (Section 1.5).

3.3.3 Scholarly Infrastructure

A key element of our human-led life-course research strategy is the establishment of incisively characterised longitudinal cohorts that are embedded across our inter-disciplinary research hubs.

Theirworld Edinburgh Birth Cohort is a £2M multidisciplinary study following 400 young people from infancy to adulthood, drawing on the ground-breaking clinical and scientific research methods developed by the Jennifer Brown Research Laboratory. It includes social, educational and clinical information, making this the first research initiative in the world to investigate perinatal brain injury this comprehensively.

FutureMS is a £2.6M nationwide inception cohort of 440 people newly diagnosed with MS, established in 2016 as a flagship Stratified Medicine Scotland programme supported by industry (Biogen and Thermofisher). This cohort has been clinically phenotyped with biological annotation

including genotyping, RNA-seq and serial imaging. The cohort will be followed-up to develop predictive tools for personalised disease course prediction and management.

National MND Research and Care Cohort is an integrated research-care-audit web-based platform that covers 98% of Scotland's people with MND (c.450 prevalent cases and c.150–170 incident cases). It enables longitudinal evaluation from diagnosis through to death including post-mortem. This cohort was central to the development of the ECAS cognitive tool for MND (**Abrahams**; **Case Study C:ECAS**) and members have been invited to enrol in our new £3.2M MND-SMART multi-arm adaptive clinical trial (**Chandran**, **Pal**).

The Lothian Birth Cohorts (LBC) were founded in 1998 by **Deary** and the late Starr (NHS) and are the longest follow-up studies of cognitive function in the world. Participants took part in the Scottish Mental Surveys of 1932 and 1947, and were followed up at multiple time-points in older age. There were 550 people in the Lothian Birth Cohort 1921 (LBC1921), and 1091 people in the Lothian Birth Cohort 1936 (LBC1936). This work has led to 25 grants worth more than £19M since 1998. More than 500 publications analyse LBC data including three very highly cited papers on genetic contributions to intelligence **[Nature 2012, PMID:22258510]**, the link between cognitive ability in childhood and old age **[Mol Psychiatry 2015]** and the impact of childhood intelligence on later life **[J Pers Soc Psychol 2004, PMID:14717632]**. The research has led to a long-term collaboration with Age UK and has informed 60 policy documents and guidelines addressing health and societal concerns that affect older people and cognitive ageing, including from the UK government, WHO and the US Centers for Disease Control.

Fig. 3.5: *LBC participants at 'reunion' day*

Generation Scotland is a cohort resource of human biological samples and health data derived from over 30,000 people from 7,000 families across Scotland. Generation Scotland underpinned the £4.8M Wellcome Strategic Award for Stratifying Resilience and Depression Longitudinally (STRADL; £4.8M, PI **A.McIntosh**), which aims to subtype major depressive disorder on the basis of its aetiology, using detailed clinical, cognitive and brain imaging assessments.

Generation Malawi has partnered with the Wellcome-funded Healthy Lives Malawi project (University of Glasgow) to create a unique £4M MRC-funded intergenerational longitudinal population study of long-term mental and physical health conditions, conducted in close partnership with three institutions in Malawi (**A.McIntosh**, **Macbeth**, **Stewart**; Fig. 3.6).

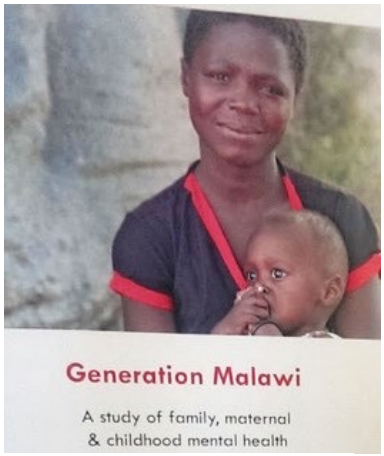

Fig. 3.6*: Generation Malawi banner*

3.4 Facilities

We have made investments in the following facilities:

3.4.1 Human research facilities

Edinburgh Clinical Trials Unit: UoE's three separate clinical trials units were formally merged in 2016. The Unit is key to Edinburgh's clinical trial strategy. It is part of the Usher Institute (UoA1) and provides comprehensive expertise and support to develop, design and deliver clinical trials. Working closely with leading clinical trial methodologists, it has been at the forefront of innovation in brain clinical trials. These include ground-breaking multi-arm and/or multi-stage national trials such as MS-SMART and the MND-SMART platform trial. In parallel, there has been serial investment in core imaging facilities to support Phase 2–3 clinical trials **[Lancet 2019; Lancet Neurol 2019]** and enable experimental medicine studies (PET-MRI).

Human MRI scanners: We have three new research-dedicated instruments (one adjacent to A&E, Royal Infirmary of Edinburgh, EBQ): two PET/CT and one PET/MR (£8M co-funded by MRC Dementias Platform UK and UoE) as part of Edinburgh Imaging (Director, **Wardlaw**). Furthermore, the new £150M Royal Hospital for Children and Young People and Department of Clinical Neurosciences at EBQ contains two research-optimised 3T MRI scanners and room for future expansion.

Electrophysiology labs: Psychology investments include mobile eye-tracking, a near-infrared spectroscopy system, an ECGMove mobile activity sensor system and state-of-the-art electroencephalogram/telemetry.

MRC Edinburgh Brain Bank (EBB), part of the UK Brain Bank Network, has been funded continuously by the MRC (£3.5M) since 2008. **Smith** directs the EBB and is Director of the UK Brain Bank Network. It provides access to richly characterised post-mortem brain tissue for researchers. EBB accepts donations from multiple national cohorts and uniquely, includes sudden death donations that provide control tissues and pathologies not covered by the key clinical cohorts, such as early-stage Alzheimer's, psychiatric conditions and drug misuse. EBB has generated highly cited publications including proteomic studies of human neocortex **[Nat Neurosci 2018]** and transcriptional profiling in epilepsy and MS **[Brain 2019, PMID:30932156; Nature 2019]**.

Human iPSC platform for drug discovery: Exploiting long-standing Edinburgh expertise in pluripotency (Dolly The Sheep was cloned in Edinburgh), we have established a brain-focussed core iPSC facility including gene-editing expertise in the UK DRI at Edinburgh. This supports all three research themes and has led to publications in mental health and neurodegeneration **[Nat Commun 2018; Mol Psychiatry 2019]**. In partnership with the co-located EBQ Edinburgh Phenotypic Assay Centre, we have established an automated high-throughput screening platform that provides world-class multi-parametric imaging-based expertise in human-based drug discovery.

3.4.2 Pre-clinical research facilities

Large Animal Research and Imaging Facility: This new (2020) £27M facility has space for six critical care beds, two full operating theatres, a 3T MRI, 64-slice CT Scanner, ultrasound

imaging, category-2 animal holding facilities and laboratory space, designed for genetically modified livestock and infectious diseases work. **Thompson** is the Medical Imaging Adviser and Co-Director (Neuro) for the Clinical Research Facility Image Analysis Core.

Edinburgh Pre-clinical Imaging consists of a rodent MRI suite with 9.4T MRI (supported by Wellcome, BBSRC and UoE; >£2M), a PET/CT suite (£800K; BHF) and ultrasound imaging facility (£500K; Wellcome) and analysis labs. A new PET/MRI will complement these facilities in 2021.

UK Zebrafish Screening Facility (part of the £2.2M 320m^2 Bioresearch & Veterinary Services Aquatic Facilities) comprises six stock rooms with associated wet labs, 3,200 zebrafish tanks linked to a £0.8M medium-content screening facility (co-funded by BBSRC, Biogen and UoE) that enables examination of fluorescence in living transgenic fish. The facility has already been used to identify compounds that enhance myelination and spinal cord regeneration.

Optical imaging platforms: We have invested £3M in six multi-photon microscopes, spinning disc confocals and four light sheet microscopes, plus fibroscopes for *in vivo* live imaging, and a virtual reality environment with simultaneous live-imaging of the brain. These facilities are underpinned by Bioresearch & Veterinary Services, whose staff oversee their provision and maintenance.

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

The driving ethos of Edinburgh Neuroscience is not only to create and grow collaborative inter-disciplinary research across the University but apply these principles to our collaborations with external partners. This begins with our community — the schools, public and patients of Edinburgh and SE Scotland — and will be enhanced by the £661M Edinburgh City Region Deal, a powerful example of bringing together government, city, UoE researchers and industry with a focus on population and health data-driven innovation. Collectively, our culture of open, collaborative, multi-partner and inter-disciplinary research is at the core of our contribution to a healthier and more productive society.

4.1 Arrangements and structures to support effective internal and external collaboration

4.1.1 Collaborative partnership with academia and industry

Edinburgh Neuroscience has invested heavily in personnel and infrastructure to support and evaluate research collaborations, build networks and partnerships. The numerous pilot / scoping events we have facilitated include multiple engagement and agenda-setting activities with patients, charities and educators.

We have prioritised developing a collaborative mindset in our ECRs and graduate students through formal structures including supervisors mandated from different disciplines (WT Translational PhD programme) and through engagement events. One example is, *each year,* 29% of our Neuroscience Day attendees (c.300) indicate they have started a new internal collaboration as a result of attending. These partnerships are then reflected in our publications: 32% of outputs submitted here are inter-disciplinary and 46% have more than one UoA4 author (Fig. 4.1).

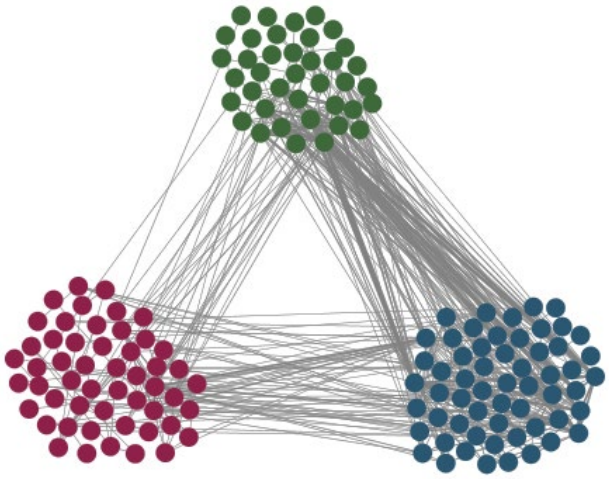

Fig. 4.1: *Internal collaboration: co-authorship across theme. Circles represent individuals (theme 1, red; theme 2, green; theme 3, blue). Lines represent co-authored publications submitted for REF2021. Line weight reflects the number of shared publications*

In this REF period >£44M has been awarded to the global initiatives we lead. We have established a new research and teaching partnership in China (£36M Zhejiang University-University of Edinburgh Institute) and grown the jointly led Centre for Developmental Synaptopathies in Bangalore, India. The Network for Studying Psychological Resilience in Low-and-Middle-Income Countries (**A.McIntosh**, **Lawrie**, **Stewart** and others) is a UKRI £180K pump-priming project with the University of Costa Rica, the University of Malawi College of Medicine and Emmanuel Hospital Association India, which led to the £3.8M MRC-funded Generation Malawi.

Our researchers lead two Fondation Leducq Transatlantic Networks of Excellence (€6M each): Perivascular Spaces in Small Vessel Disease (**Wardlaw**) and Stroke - Immune Mediated Pathways and Cognitive Trajectories (**McColl**). Our cross-disciplinary partnership with the Brain Centre Rudolf Magnus continues, with 30 funded students visiting Utrecht while, in 2019, we established a new research partnership in neurodevelopment and degeneration with McGill University, Canada, providing c.£150K annual funds to support three jointly led projects per year.

In addition to these larger initiatives, our researchers collaborate widely with researchers across the globe, and have co-authored publications with academics in 119 countries (Fig. 4.2). Some 57% of publications (n=3255) had international co-authorship (2014–2020, Scopus).

Fig. 4.2: *International collaboration in terms of joint authorship. Circle size represents the number of shared publications.*

We have grown our partnerships with industry by 60% since REF2014 to 13 (awards worth £9.6M), including major multi-year discovery programmes, e.g. Janssen £4.8M. Almost 10% of our

publications recorded in Scopus 2014–2020 have both academic and corporate authors. We have launched three spin-out companies: PhenoTherapeutics (**Chandran,** with Carragher UoA1), AstronauTx (**Hardingham**) and SpeakUnique (**Chandran**). These demonstrate inter-disciplinary research, linking founders from cancer–neuroscience, or informatics–neuroscience.

4.1.2 Collaboration with government

Our researchers actively contribute, by providing expert advice, to policy-making worldwide. 12% of our researchers are members of policy advisory panels and committees that address issues affecting people throughout the life-course. This ranges from healthy body image for children and young people (**Sharpe**, **Duffy**), adverse childhood experiences (**Johnson**), online child abuse and offending (**Quayle**; Scottish Government, WHO and UN task forces), to prisoner brain injury and offending (**O'Rourke**), mental health services (**O'Rourke**, **Lawrie**, **Schwannauer**), healthy ageing (**Deary**) and dementia (**Spires-Jones**). **Green**, **Knight**, **Manson** and **Smith** advise on CJD and prion-related health and safety issues, including for the 'Dangerous Pathogens' and 'Safety of Blood Tissues and Organs' committees, National Institute for Health and Care Excellence (NICE) and WHO (**Case Study J:vCJD surveillance**).

Our researchers also contribute to national and international drug and treatment regulation and recommendations, e.g. Medicines and Healthcare Products Regulatory Agency and European Medicines Agency (**Hunt; Case Study I:TMA**).

Non-committee policy work includes a Consultation for the Northern Ireland Department for Communities on the cognitive effects of language learning and practice (**Bak**), while **Schwannauer** contributed to the schizophrenia section of 'The Matrix: A guide to delivering evidence-based Psychological Therapies in Scotland', which is used by Scottish Government for service planning.

4.1.3 Collaboration with the NHS

Core to our vision for human-led research is the creation of an integrated care-research model, e-health infrastructure and data linkage assets whereby every health contact (for care) represents an opportunity for new knowledge. This sits squarely with our belief that the best health *care* is inseparable from the best health *research*. This agenda is driven by and through The Academic and Clinical Central Office for Research and Development (ACCORD): a partnership between UoE and NHS Lothian Health Board that provides an integrated streamlined regulatory support and public/patient engagement framework for all clinical research.

One example of successful partnership between the NHS and University is the Anne Rowling Clinic that delivers integrated frontline NHS care (40 clinics per week) with cutting-edge clinical enabled research ranging from observational and interventional trials to biological sampling of deeply phenotyped cohorts (including MND, MS, early-onset dementias, venous malformation, functional neurological disorders, Parkinson's) for discovery studies. The seamless integration of NHS–University is further reflected in the numbers of clinically active researchers (24% of the return), who also lead major NHS clinical themes. These include Head of NHS Neuroinflammation Medicine (**Hunt**) and Stroke Medicine (**Dennis, Wardlaw**). Finally, we have prioritised support and integration of NHS academics who are Honorary University researchers. Examples include Carson and Stone who lead Functional Neurological Services, Riha who leads Sleep Medicine and Russ who directs the Alzheimer's Scotland Dementia Research Centre.

4.1.4 Collaboration with the third sector, public and patient groups

Ensuring our research is relevant requires prospective and continued bi-directional engagement with key stakeholders and potential beneficiaries (example, Fig. 4.3).

Fig. 4.3: *The Muir Maxwell Epilepsy Centre produced an educational animation inspired by children with epilepsy (2018; 1,645 views on YouTube)*

Furthermore 24% of our researchers contribute time and expertise to 69 patient-facing charities, including as grant reviewers (e.g. Alzheimer's Society, Alzheimer's Research UK, Epilepsy Research UK), scientific advisors (e.g. Bipolar Scotland, Fragile X Society, Muscular Dystrophy UK, MQ, MS Society, Epilepsy Action, Stroke Association) or Trustees/Patrons (Cavernoma Alliance UK, Scottish War Blind, Royal Blind). Two new charities have been founded by our researchers: SuperTroop (**Fletcher-Watson**, 2017) and African Alliance for Maternal Mental Health (**Stewart**, 2018). **Fletcher-Watson** was awarded a Certificate of Excellence by Autism Rights Group Highland (2018) for 'amplification and inclusion of autistic voices in research'.

Fig. 4.4: *Euan MacDonald, who has MND, is a regular visitor to the research laboratories and helped drive the MND-SMART launch campaign*

Our research engages directly with patients across the UK and internationally. The recruitment campaign for the **MND-SMART clinical trial platform** (2020), featured Euan MacDonald (founder of the Euan MacDonald Centre research hub) (Fig. 4.4). It reached over 11 million people in the first week (lead item on the BBC 6 o'clock and 10 o'clock television news), was covered in 500 media print articles and received extensive social media coverage. This encouraged over 1100 people — 20% of the UK MND patient pool — to sign up within 6 weeks.

The **Functional Disorders website**, neurosymptoms.org, established and maintained by Stone and Carson (both NHS), has enormous reach: >9 million visits since 2009 (up from 0.5 million in REF2014), providing valuable information for an under-represented patient group.

Researchers at the Patrick Wild Centre continually engage with families affected by Fragile X Syndrome, including a **family-in-residence programme** where, over a year, a family with two children with Fragile X visited research laboratories and welcomed research scientists to their home. This was shortlisted for a Times Higher Education Leadership and Management award (2017). In 2018 the **Dundee-Edinburgh Parkinson's Research Initiative** was established by neurologists **Chandran** and **Breen** with fundamental researchers **Hardingham**, Kunath (UoA5) and colleagues in Dundee led by Alessi. This initiative brings together patients and researchers for talks and discussions — patients read prospective research grant application lay summaries — and has recently funded two PhD students, one based in each city.

Dementia 'Buddy Pairs' brought patients and carers into the University to meet researchers and take part in lab meetings. Pioneered by Henstridge (was UoE, now Dundee) with Wilkinson (UoA20), this successful scheme resulted in a publication **[Dementia, 2019, PMID:31718269]**.

Fig. 4.5: *In 2019 PhD students worked with the FOXG1.UK charity to produce website content*

Our PhD students are trained to engage directly with patient groups and families. Students in the SPRINT-MND/MS cohort have attended professional training in patient/public engagement and have travelled to Glasgow and Aberdeen to participate in patient/public events. In 2020, the Translational Neuroscience PhD students worked with FOXG1 families to understand their information needs and create bespoke content for the FOXG1.UK charity website. Their work changed the charity's perspective on how they provide information for their community.

4.2 Wider contributions to the economy and society not captured by impact case studies

Our impact is lasting and sustainable. Revised feeding regimes recommended for stroke patients by **Dennis** (REF2014 case study), remain in place and continue to save the NHS £12M a year, reducing death and disability rates by 1,900 each year. Similarly, not recommending compression stockings to prevent deep vein thrombosis in post-stroke patients continues to prevent the NHS from unnecessarily spending £20M per year and saves 6,000 people a year from complications.

The creation of the 'Staying Sharp' booklet and website in 2018 in collaboration with Age UK (**Deary**, **Bak**, **Wardlaw**) continues the Lothian Birth Cohorts impact from REF2014; it has been seen by over 100,000 people.

After undertaking a survey in 48 countries, **Brennan** campaigned to standardise the worldwide use of the Glasgow Coma Scale (used to assess people with head injury) **[J Neurotrauma 2016, PMID:25951090]**. As a result, he developed GCSAid, a standardised tool now freely available. Further research has resulted in the addition of the pupillary response (GCS-P) **[J Neurosurgery 2018, PMID:29631516]**.

Wardlaw, **Salman**, **Whiteley**, **Macleod** and Sudlow (UoA1) undertook a systematic review of potentially serious incidental findings identified in 27,643 brain images **[BMJ 2018, PMID:30467245]**. They found that advice on how to deal with these was poorly formulated and inconsistent, so convened a formal national discussion, including the MRC and Wellcome. This resulted in a position statement that has been adopted by UK Biobank, (which aims to conduct brain and body MRI of over 100,000 participants), saving money for the NHS by reducing the number of futile follow-ups and avoiding unnecessary patient distress.

Bak's research revealing that bilingualism leads to a delay in the age of dementia onset **[Neurology 2013, PMID:24198291]** and improved cognitive outcome after stroke **[Stroke 2015, PMID:26585392]** led him, in 2015, to co-establish a new social enterprise, Lingo Flamingo. This delivers language classes to older adults and dementia patients in nursing homes and community settings across central Scotland. Informal feedback is very positive with participants appearing more engaged with activities. Lingo Flamingo-style classes are now being established internationally.

Neurosurgeons **Brennan** and Hughes (NHS) identified a need among surgeons and launched multi-award-winning spin-out company eoSurgical in 2012 to design and manufacture mobile laparoscopic simulators and software to improve surgical training. Now with six simulation models, it is used in over 80 countries. eoSurgical also offers scholarships to students from low-and-middle-income countries to undertake distance-learning surgical science degrees.

A partnership between the Euan MacDonald Centre (**Chandran**, **Bak**) and UoE Informatics led to SpeakUnique, a spin-out company supported by Edinburgh Innovations that launched in 2020. An idea sparked by MND patient Euan MacDonald, SpeakUnique uses personalised voice synthesis to give people who have lost the ability to speak (e.g. MND, throat cancer, stroke) a voice of their own that matches their gender, age and regional accent.

During the COVID-19 pandemic, **Thompson** and colleagues addressed the impact of masks and face-coverings on exhaled airflow, informing government advisory groups including SAGE. **Sandercock**, an internationally recognised expert in trial oversight, chaired the Independent Data Monitoring Committee of the RECOVERY trial leading to changes in intensive care treatment for COVID patients worldwide.

4.3 Engagement with diverse communities and the public

Our community is committed to two-way engagement with the public; 30% of researchers participate directly in external outreach. Contributions to public engagement and outreach are recorded in annual staff development reviews and in 2019 we identified an academic lead for

public engagement, **Rhodes**. We follow a strategic aims and principles approach to guide our work: aiming to reveal, involve and embed engagement practices, underpinned by partnership, training and evaluation. We were delighted to welcome a student in the first cohort of the UoE Engagement for Impact PhD programme (Lead, Davidson UoA1) to Edinburgh Neuroscience, supervised by **Rhodes**.

Public involvement in our research has come to the fore during the COVID-19 pandemic. Our researchers rapidly initiated five surveys: CovidLife/TeenCovidLife (Generation Scotland - mental health during lockdown; COVID-19, Sleep and Mood (Riha, NHS), Teenage Irritability (**Whalley**) and CoronaReport, which assesses social implications (**J.Mirman**). **Macleod** and Sena (UoA1) harnessed the global researcher community to create a systematic and continually updated online summary of COVID-19 evidence.

Our outreach programme has directly reached over 4,000 school pupils and 21,000 members of the public, while our online talks have been viewed 53,000 times. Our online social media activity reaches an average of 414,000 people a year.

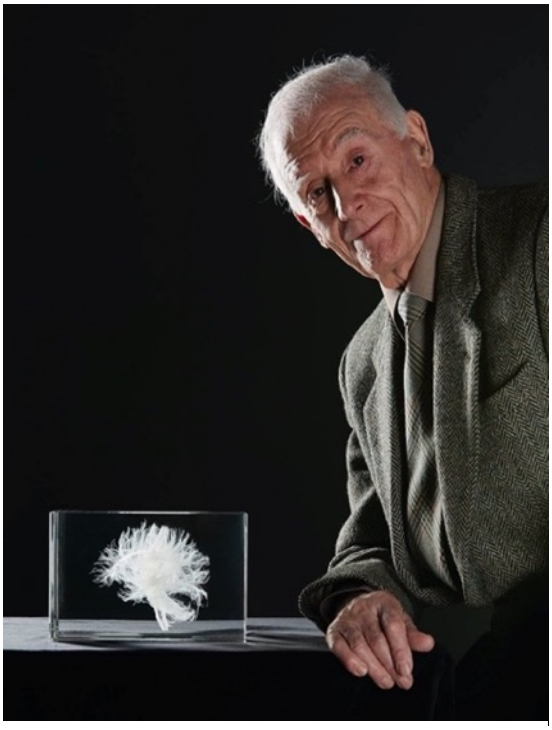

Fig. 4.6: *Diverse means of engagement. In 2016 a glass etched MRI brain scan of one of the Lothian Birth Cohort participants was donated to the Museum of Scotland, where it is on display*

We use a variety of engagement approaches to reach different communities (Fig. 4.6), including lectures, film, science-theatre, art, yoga, festivals (science and arts), schools, youth groups and social media. Our annual public Christmas Lectures attracted 1,839 attendees in REF period plus 7,719 online views. At twice-yearly drop-in research open evenings hosted by the Anne Rowling Clinic, each attracting 50–100 people, ECRs and PhD students discuss and demonstrate their research with patients and families.

We have worked with brain surgeons, paramedics and brain injury survivors to deliver '**Neurotheatre: simulated brain surgery**' a theatre-style production that takes the audience through brain injury treatment (with very realistic surgery) through to rehabilitation. This incredibly popular event reaches 250 people a year (mostly teenagers) and is being adopted by Brown University, USA.

In 2014, we launched **FUSION**, our monthly art-neuroscience group, partnering with Edinburgh College of Art and independent local artists. The creative interactions between these quite different groups have led to exhibitions at Neuroscience Day (c.300 neuroscientists) and Pint of Science (twice, 110 public). The Anne Rowling Clinic exhibits a rotating display of artworks by UoE art students and hosted 'Portraits of the Brain': a series of three student-led art workshops for people with MS.

Fig. 4.7: *'The Brain - is Wider than the Sky' outdoor science-art exhibition in central Edinburgh*

Also in 2014 **'The Brain - is Wider than the Sky',** an outdoor science-art exhibition in collaboration with the charity Mindroom, ran for 7 weeks at St Andrews Square, in the heart of Edinburgh, and received widespread national media coverage (Fig. 4.7).

Our 2015 mini-movie **'Ages of the Brain - A Day in the Life of Edinburgh Neuroscience'** was created by our research community with an MSc Science Communication student (>3500 views on YouTube). We have undertaken regular film screenings for adults and children, with researchers talking about work relevant to the film.

We worked with the Edinburgh Science Festival in 2015 to produce '**Brainwaves**' a neuroscience-themed strand with 24 events, plus a walking 'neurotrail' map of Edinburgh (4000 distributed). **Chin**, **Horsburgh**, **Lawrie** and Oren (former staff) partnered with a yoga instructor to deliver '**Neuroyoga**', an evidence-based panel discussion on whether yoga influences brain and body function, concluding with an audience yoga session. This has been delivered at the Edinburgh, Glasgow and Midlothian Science Festivals (110 participants). **Bak**, **Lawrie**, Stone (NHS) and **Schwannauer** regularly contribute to the Edinburgh Fringe Festival 'Cabaret of Dangerous Ideas'.

Fig. 4.8: *Example embroidery of a Purkinje neuron, part of the Cajal Embroidery Project*

To celebrate 100 years since the founding of the Cajal Institute in Madrid, the '**Cajal Embroidery Project**' was conceived as an exhibit for the Federation of European Neuroscience Societies

(FENS) Forum Glasgow 2020. Unexpectedly providing inspiration during COVID-19 lockdown, it united 77 scientists, crafters, artists and professional embroiderers from seven countries to produce 81 embroideries of Cajal's illustrations (Fig. 4.8) to be combined into a single piece of science-art. It was published in *Lancet Neurology* (2020; **doi.org/10.1016/S1474-4422(20)30348-3**) and features on the front cover of this journal throughout 2021.

4.4 Contributions to, and recognition by, the research base

4.4.1 Contribution to Science Publishing

37% of our researchers (up from 18% in REF2014) undertake roles as journal editors, or serve on editorial boards, including *Science*, *Nature Communications*, *Nature Science Reports*, *Glia*, *Lancet Neurology*, *Cell Reports*, *Brain*, *eLife, Molecular Psychiatry.* Five are Editor-in-Chief (with two starting new journals in REF period): *J Anatomy* (**Gillingwater**), *Curr Opin Physiol* (**Ribchester**), *Brain Communications* (**Spires-Jones**), *Cortex* (**Della Salla**) and *Psychology and Psychotherapy* (**Schwannauer**). **Fletcher-Watson** was listed as a top peer reviewer on Publons – the most reviews for UoE, 2017. **Macleod** and Sena (UoA1) have made major contributions to help publishers improve the validity of experimental research (Section 1.4; **Case Study G:Rigour**).

4.4.2 Membership of grant- and Fellowship-awarding bodies

24% of our researchers (up from 17% in REF2014) serve on 80 grant-awarding panels in the UK and internationally (39% for charity funding panels) including: British Academy, MRC, Wellcome, NIH, with **Spires-Jones** Chair of Alzheimer's Research UK grant-awarding panel**, ffrench-Constant** Chair of Wellcome Molecular Cellular and Neuroscience Expert Review Group, **A.McIntosh** Chair of MQ Data Science Grants Committee, **Price** Vice-chair of the MRC Board funding international research to generate an Atlas of Human Cell Types and **Logie** on the ERC Advanced Researcher Panel.

4.4.3 Committee membership of Professional bodies, Charities and Trusts

15% of our researchers actively contribute to the vibrancy of learned societies (e.g. Royal Society, Physiological Society, British Neuropathological Society, FENS, International Brain Research Organization, International Neuropsychological Society) with significant roles on committees and boards, including six Presidents/Chairs: **Leng**, **Logie**, **R.Morris**, **Valdes-Hernandez**, **Sandercock**, **Smith**.

17% of our researchers hold expert advisory positions including: International Consulting Fellow for the World Innovation Foundation (**Grant**), Advisor to UN Office on Drugs and Crime (**A.Murray**), NICE Guideline Development Group for Motor Neurone Disease (**Abrahams**), Paediatric Medicines Expert Advisory Group (**Chin**), NHS England CSF Prion Health and Safety Concerns (**Green**), Medicines and Healthcare Products Regulatory Agency and European Medicines Agency (both **Hunt; Case Study I:TMA**), UK Commission for Human Medicines (**Macleod, Owens**), UK Home Office Animals in Science Committee (**Macleod**) and Secretary of State for Transport's Honorary Medical Advisory Panel on Driving and Disorders of the Nervous system (**Salman**).

4.4.4 Honours, fellowships and other awards

Within REF period, 27 researchers were elected Fellows of 16 different societies including: Royal Society of Edinburgh (**Chandran**, **ffrench-Constant**, **Hardingham**, **Price**, **Macleod**, **Lawrie**), Academy of Medical Sciences (**ffrench-Constant**, **Hardingham**, **Grant**), Fellow of the Royal Society of Biology (**Becker**, **Fleetwood-Walker**, **Gillingwater**, **Macleod**, **Manson**, **Shipston**), World Stroke Organization (**Sandercock**, **Wardlaw**), plus two elected to the Royal Society of Edinburgh Young Academy Scotland **(Brennan**, **Rhodes**) and eight to the Higher Education Academy (**Gillespie-Smith**, **Hampton**, **Hernandez**, **Romano**, **Salman**, **Sharpe**, **Stefan**).

Deary, **Harris**, **A.McIntosh**, Starr (deceased) and **Wardlaw** were named Highly Cited Researchers in 2019 and 2020 by Web of Science.

Our Undergraduate students have been recognised for their Honours dissertation projects: six were awarded the Annual British Neuroscience Association Undergraduate Award over the past 7 years (only missing out in 2018).

Fig. 4.9: *Jane Haley, Edinburgh Neuroscience Scientific Coordinator, received an MBE in 2019 for services to Science Engagement and Education*

Our researchers have been recognised with a number of very high level awards, including **R.Morris**, jointly awarded the 2016 Brain Prize and the 2020 Fondation Fyssen Prize in Neuroscience for his work on the mechanisms underlying memory, plus the Royal Society of Edinburgh 2014 Royal Medal for contribution to science. **Deary** was awarded a Lifetime Achievement Award from the International Society for Intelligence Research in 2014, and **Sandercock** received the UK Stroke Forum Lifetime Achievement Award (2015). **Wardlaw** received the 2017 European Stroke Organisation Presidential Award and **Dennis** the 2018 British Association of Stroke Physicians President's Award.

Quayle (2018) and **Wardlaw** (2016) were appointed CBE for contribution to the online safety of children and services to clinical medicine and neuroscience, respectively. **Deary** was made an OBE (2019) for services to the social sciences, and Haley (Scientific Coordinator) an MBE (Fig. 4.9).