Institution: The University of Edinburgh

Unit of Assessment: 5

a. Overview

Biology at the University of Edinburgh has a long history of breaking new ground, having contributed substantially to the foundations of modern genetics, evolutionary biology, molecular biology and systems biology. Today, we continue that tradition of delivering high-quality research in areas fundamental to addressing the big scientific questions of today (evidenced by the publication during the REF period of 78 primary research papers in the three influential journals **Cell, Nature** and **Science**) and capable of delivering solutions to global challenges. Our distinctive capabilities are captured by our three thematic areas of research.

Cell and Structural Biology (CSB): What are the fundamental mechanisms and structures that underpin genomic and cellular function, stability, and development? By addressing these questions this Theme aims to impact health, ageing and disease; and the development of therapeutic drugs.

Evolution, Infection and Immunity (EII): How do organisms evolve? Can the causes and consequences of disease be understood by integrating evolutionary genetics, ecology and epidemiology with fundamental immunology and pathogen biology? By combining quantitative and theoretical methods with field and laboratory studies this Theme aims to gain unique insights into evolving systems and contribute to the prevention and treatment of disease.

Systems and Synthetic Biology (SSB): Can we model *in vivo* behaviour and design new synthetic systems? By integrating biological and physical data with mathematical models, this Theme seeks to understand dynamic processes on scales ranging from molecules to whole organisms and to engineer rationally-designed synthetic systems.

Our strength lies in our people. We benefit from a large, diverse School of Biological Sciences with over 110 principal investigators and 500 research staff and graduate students included in this submission. We have successfully encouraged and supported collaborative research; the integrated Themes outlined above reflect our ethos of **collaborative and interdisciplinary working**. Many staff also work across more than one Theme and with disciplines outside biology. The success of this approach is shown by the omission from this UoA of our pioneering work in stem cell biology. Following the very successful integration of this research within the new Centre for Regenerative Medicine, our stem cell biologists are now returned with UoA1.

Major discoveries in each Research Theme illustrate how our research is **transformative**. The development of therapeutic strategies to treat Rett Syndrome is underpinned by the discovery that the disease is caused by the failure of MeCP2 to deliver the NCoR/SMRT co-repressor complex to DNA (**Rappsilber** and **Bird,** 2013). How we think about wound healing and cancer therapy was changed by the discovery that inflammation can be caused by a localized proliferation of macrophages already at a site of infection (rather than recruitment from the blood) (**Allen,** 2011). New ways of thinking about biological rhythms are now possible following the paradigm-shifting discovery that metabolic oscillations underpin the functioning of the circadian clock (**van Ooijen** and **Millar,** 2011).

Our **high-ranking position** in international benchmarks for quality in the biological sciences reveals the esteem in which we are held: we are ranked 19th in the 2013 QS World University Rankings (5th in Europe, 4th in UK); 21st in the 2013-2014 THE World Ranking (6th in Europe, 5th in UK); 35th in the 2013 Shanghai World Ranking (7th in Europe, 4th in UK).

b. Research strategy

Investing in people Our strategy is founded on the excellence of our researchers. Recognition of this excellence across our Research Themes is afforded by the election (in the REF period) of **Allshire, Earnshaw, Millar** and **Sharp** to **FRS** plus numerous awards and medals to other staff (**e3**). We have aggressively built capacity in our strategic Themes through targeted hiring. In total, 49 staff have been recruited during the REF period across our three Research Themes. These include 18 externally-funded fellows, 12 university Chancellor's fellows (CF, early-career tenure-

track appointments), 4 university research fellows (UF), 9 lecturers, 3 readers and 3 professors. A fourth new professor joins us on 1st November 2013. To train the next generation of scientists, we are the lead institution for the largest BBSRC Doctoral Training Partnership (**c5**).

Investing in infrastructure More than £20M has been invested in infrastructure and facilities. We have secured major equipment funding from both RCUK and charitable sources and have made significant institutional investments in equipment for drug discovery, synthetic biology and imaging; and in the renovation of buildings to better accommodate research into infectious disease (**d2-3**). We have made use of our Wellcome Trust (WT) Institutional Strategic Support Fund (£2M per annum matched investment with the University, since 2011) to enhance equipment, to support key strategic staff appointments, and to provide seed-funding for new interdisciplinary initiatives.

Enabling collaboration Our aim is to continue to carry out world-class research and we understand that interdisciplinary collaboration is vital in today's highly diverse and technologically-demanding environment. Therefore, since 2008, we have strengthened our links to other Schools and Colleges within the University. One effective strategy has been the creation and support of Research Centres with an explicit remit to foster collaboration with other disciplines. We now have close working relationships with chemistry, engineering, geosciences, informatics, mathematics and physics as part of the College of Science and Engineering. Interactions with clinical researchers are facilitated by the proximity of the School with the University's new medical and veterinary campuses.

b1. Achievement of our overall strategic aims Through the strategy and investment outlined above, we have realised all of the aims we set out in RAE2008 to build new interdisciplinary and collaborative initiatives, and to ensure continued development of our core disciplines. In particular, we have promoted the integration of life and physical sciences research and encouraged the translation of fundamental research into practice. Furthermore, we can now group all of the research within this unit of assessment into just three broad and interdisciplinary Themes (**a**), each of which has clear opportunities for delivering solutions to global challenges in health and the environment.

Part of the strategy set out in RAE2008 was to establish two new Research Centres: a Centre for Immunity, Infection & Evolution, and a Centre for Synthetic Biology. The former is now well-established (**b2 B**), having secured £3.9M in WT core funding during the REF period, and forms a key component of our second Research Theme. We created the latter as SynthSys (pronounced "Synthesis"), a centre with a combined focus on synthetic and systems biology, which contributes substantially to our third Theme (**b2 C**).

In 2008 we had just established SULSA, the Scottish Universities Life Science Alliance, a partnership of six Universities (with Aberdeen, Dundee, Glasgow, St Andrews and Strathclyde) with £27M investment from the Scottish Funding Council (£7.4M investment at the University of Edinburgh over the REF period). Our aims for SULSA investment were to strengthen our core competency in cell biology, to develop systems biology, and to support interdisciplinary and translational research, particularly in drug discovery. We have achieved all of these aims, as set out below, and have sustained and extended them with £12M of further institutional investment. SULSA now plays a key role in coordinating collaborative and translational opportunities across Scotland and has been extremely successful in attracting inward commercial investment based on the combined academic research capabilities of the partner institutions (**c5, d3** and **d4**)

In addition, we have successfully launched the MRC Centre for Regenerative Medicine (CRM). This collaborative activity with College of Medicine and Veterinary Medicine (£2.8M MRC renewal funding in 2013, building on £1.9M MRC award in 2008) has fully integrated fundamental stem cell biology with translational medical research and all of these scientists are now returned within UoA1. The CRM moved into purpose-built accommodation in 2011 (£54M).

b2. Research Themes, activities and achievements

(A) Cell and Structural Biology (CSB) (41 primary members of academic staff; Research income in REF period: £52.3M; Steering Group: Finnegan, Walkinshaw, Tollervey) This well-established grouping investigates fundamental biological processes at the level of cells, molecules and genes. As planned in RAE2008, we have successfully promoted collaboration between cell, molecular and structural biologists to create this single integrated Theme, exploiting world-leading

innovation in biophysical and imaging methods, protein-nucleic acid interactions and mass spectrometry. The main topics of this Research Theme are gene expression and RNA biology, cell architecture, growth and division, and genome stability. We have particular strengths in the study of gene expression in developing systems, particularly epigenetic processes such as DNA methylation, the impact of epigenetics on gene expression and the manipulation of epigenetic mechanisms; in RNA structure and function, including transcription, processing, transport and turnover; in the cell division cycle, focusing on the structure and segregation of chromosomes; and in cell signalling and development. We have the capacity to interrogate protein structure by X-ray crystallography, NMR, mass spectrometry and cryo-EM, and to probe biophysical and biochemical features and interactions (such as protein-ligand binding) informed by structural information. These technologies allow the comprehensive characterization of biomolecules of importance for fundamental cell biology and drug discovery. Central to this Theme is our **Wellcome Trust Centre for Cell Biology** (**WTCCB**: Director Tollervey; 5 members are FRS), which has an international reputation for discovering fundamental cellular processes. The WTCCB's core award was renewed in 2011 (£5M for research fellowships, core services and infrastructure; the preceding 2006-11 award was £3.6M); it also runs a WT-funded PhD programme (£750k per annum since 2008). The following examples illustrate the diversity and quality of our science in this Theme:

- The demonstration that leading- and lagging-strands of DNA are segregated to different cellular locations providing a model for the 'immortal-strand hypothesis' (**Leach** 2008, **Nature** 455);
- The first structure of a eukaryotic transposition complex shedding light on the mechanism of DNA transposition (**Richardson**, **Finnegan** and **Walkinshaw** 2009, **Cell** 138);
- The elucidation of the mechanism of action of the NPR1 protein, a master activator of plant immune genes (**Spoel** 2009, **Cell** 137);
- The finding that some small silencing RNAs in plants are mobile and direct epigenetic modification (**Molnar** 2010, **Science** 328);
- The identification of the protein composition of mitotic chromosomes using a novel combination of proteomics and machine learning (**Earnshaw** and **Rappsilber** 2010, **Cell** 142);
- The description of a key protein that couples RNAi to chromatin modification and directs centromeric heterochromatin formation (**Bayne, Rappsilber** and **Allshire** 2010, **Cell** 140);
- An elucidation of the function of non-methylated CpG islands due to their effect on chromatin structure (**Bird** 2010, **Nature** 464);
- The discovery of diverse classes of mRNAs and non-coding RNAs distinguished by 3' ends and processing pathways (**Tollervey** 2013**, Cell** 154).

In the REF period we have strengthened structural biology through 4 appointments: **Böttcher** (readership, cryo-EM of macromolecular complexes, £1.4M WT and Darwin Trust), **Cook** (MRC CDA, complexes involved in RNA metabolism, £1.5M), **Jeyaprakash** (WT CDF, structural biology of cell division, £880k) and **Spagnolo** (lectureship, protein nano-machines). We have strengthened drug discovery expertise via recruitment of **Auer** (SULSA professorship, innovative drug discovery, £2.8M) and **Houston** (lectureship, virtual screening). We have extended core cell biology capability through a further 6 new staff: **Bayne** (MRC CDA, non-coding RNAs in genome regulation, £1M), **Makovets** (MRC CDA, telomere biology, £900k), **Michlewski** (MRC CDA, regulation of microRNA biogenesis, £1.3M), **Serrels** (UF, cell polarization mechanisms), **Welburn** (CRUK RF, regulation of microtubules in mitosis, £1.1M) and **West** (WT CDF, nuclear pre-mRNA surveillance, £700k). Plant cell biology has been enhanced through the appointment of **Nagy** (SULSA professorship, photobiology, £0.5M**)** and **Spoel** (RS URF, signalling and transcription, £600k). Recruitment of **Molnar** (CF, epigenetic control by small mobile RNAs) heralds future expansion of our epigenetics capability. We are also currently recruiting to a newly-established Chair in epigenetics.

(B) Evolution, Infection and Immunity (EII) (52 primary members of academic staff; Research income in REF period: £51.5M; Steering group: Pemberton, Gray, Matthews) EII is our largest and most wide-ranging Theme that builds on our long-standing international reputation for evolutionary biology and exemplifies our success in interdisciplinary research. With one of the largest groupings of evolutionary biologists in the world, our research integrates quantitative and theoretical methods with field and laboratory studies of evolutionary genetics, genomics, evolutionary ecology and behaviour. Uniquely, EII is equipped to explore evolution from the scale of a single gene through to entire communities. Evolution underpins all of biology and has particular

relevance for infectious disease research, where pathogens multiply in large numbers and respond rapidly to selective pressures such as drug therapy, climate and habitat change, and host migration. Combining our evolutionary genetic expertise with research at the interface of fundamental immunology, pathogen biology, genetics and epidemiology, we aim to support the development of new interventions to control human and animal diseases or to predict disease outbreaks or therapeutic breakdown. Our key research topics are molecular evolution and genomics, genetics of complex traits, life history and mating system evolution, behaviour and social evolution, speciation and biodiversity, host-parasite interactions and virulence evolution, and fundamental pathogen biology and immunology. The Theme encompasses an exceptional breadth of pathogen research, from viruses to helminth parasites, and applies a wide array of scientific approaches from functional genomics to mathematical biology. Our WT-supported **Centre for Immunity, Infection and Evolution** (**CIIE**: Director Matthews) facilitates collaborations beyond the Biological Sciences, e.g. between basic and clinical scientists, and between empirical and mathematical approaches, to develop new strategies for combating infectious disease by combining molecular, cellular and genomic data within an evolutionary context. The WT renewed its funding for CIIE through a Strategic Award in 2011 (£2.4M to fund interdisciplinary research fellowships and infrastructure, building on a £1.5M Wellcome development award in 2008). CIIE has also secured £1M from the Wolfson Foundation to support laboratory refurbishment. The following examples illustrate the diversity and quality of our science in this Theme:

- The discovery that malaria parasites adjust their sex ratio to optimise their transmission in response to competition (**Reece** 2008, **Nature** 453);
- Mapping of the origins of the 2009 H1N1 influenza pandemic (**Rambaut** 2009, **Nature** 459);
- Identification of the surface transporter for the trypanosome differentiation signal, also providing the first marker for parasite transmission (**Matthews** 2009, **Nature** 459);
- Demonstration that natural selection maintains heritable variation in antibody responsiveness in the wild (**Nussey** and **Pemberton** 2010, **Science** 330);
- The discovery that the most malign human malaria parasite, *Plasmodium falciparum*, originated in gorillas (**Sharp** 2010, **Nature** 467);
- Confirmation of the fundamental prediction that males vary more in their reproductive success than females (**Walling** 2010, **Science** 328);
- The discovery that local macrophage proliferation is an alternative form of inflammation that does not require blood cell recruitment (**Allen** 2011, **Science** 332);
- Evidence that climate change delays (rather than advances) phenology in a wild mammal, with corresponding fitness costs (**Kruuk** 2012, **Nature** 489).

During the REF period, we have focused on strengthening our interdisciplinary research capacity in immunology, host-pathogen biology and their interfaces with evolution through 10 appointments: **Brown** (readership, social evolution in bacterial pathogens), **Buck** WT CDF, microRNA function in the host-pathogen context, £840k), **Ivens** (UF, bioinformatics for genome analysis), **Obbard** (WT CDF, evolution of insect viruses and insect immune systems, £665k), **Pederson** (CF, disease ecology and wild immunology), **Potocnik** (CF, lymphocyte development), **Schnaufer** (MRC CDA, mitochondrial biology of trypanosomatid parasites, £1.3M), **Spence** (CF, pathogen virulence), **Szoor** (UF, phosphatases in parasite biology), **Zaiss** (CF, immunology). We have also recruited 7 academic staff in quantitative genetics and genomics, matching our RAE2008 commitment to invest in this area: **Gharbi** (UF, SNP and QTL mapping), **Hadfield** (RS URF, evolutionary quantitative genetics, £532k), **Jones** (lectureship, evolutionary bioinformatics), **Lohse** (NERC RF, speciation genomics, £330k), **Moorad** (lectureship, evolution of ageing), **Ross** (NERC RF, genetic conflict, £605k), **Walling** (NERC RF, trade-offs and the evolution of life history traits, £530k). We have made 4 appointments in evolutionary ecology and behaviour, giving us renewed strength in this area as planned in RAE2008: **Bell** (lectureship, evolution of social conflict), **Phillimore** (NERC Advanced RF, macro-ecology and macro-evolution, £670k), **Smiseth** (lectureship, animal behaviour), **Walsh** (lectureship, behavioural ecology and cognition).

(C) Systems and Synthetic Biology (SSB) (19 primary members of academic staff; Research income in REF period: £18.6M; Steering group: Millar, Swain) SSB is our most recently-created and rapidly developing Theme, bringing together aspects of biotechnology, imaging, systems modelling and synthetic biological design. In systems biology we integrate biological data

and mathematical models into large-scale informatics infrastructures and apply novel tools to understand a range of dynamic biological processes. Current interests include RNA metabolism and cell polarity in yeast, plant growth and the circadian clock, and new chemical rate equations for systems biology modelling. We have established imaging systems that enable the analysis of stochastic gene expression on a cellular and single-molecule basis. Our broad modelling capabilities combined with experimental and biotechnological approaches have enabled us to develop new research directions in synthetic biology including cell modelling, the creation of synthetic chromosomes, the development of biosensors, and the production of novel materials in plants and microorganisms. Key technology platforms include computer-aided design and simulation of biological devices and systems, customised DNA synthesis and robotics for high-throughput genetic and phenotypic assays. This growth in capacity has been enabled by closer integration of the physical, computational and life sciences across the University. We have driven this integration by the creation of **SynthSys**, our interdisciplinary Research Centre for synthetic and systems biology, which includes members from the life, physical, engineering and social sciences (Director: Danos, Informatics). We created SynthSys in 2012 as an expansion of the successful BBSRC Centre for Systems Biology at Edinburgh (CSBE, set up in 2007 with a grant of £11M from BBSRC and EPSRC). Recent major collaborative awards in synthetic biology and biotechnology coordinated by SynthSys include the £5M **EPSRC Flowers Consortium Award** to establish platform technology in synthetic biology (Edinburgh is one of five partners) and the **Industrial Biotechnology Innovation Centre** (**IBIC**) led by the University of Strathclyde (£10M from the Scottish Funding Council and £25M projected from industry; Edinburgh is one of two universities on the Board). The following examples illustrate the diversity and quality of our science in this Theme:

- Demonstration that the classic Michaelis-Menten equation of enzyme kinetics breaks down due to intrinsic noise, even under steady-state conditions (**Grima** 2009, **Phys Rev. Lett.** 102);
- Model-based rewiring of yeast cells to make two buds (**Goryachev** 2009, **Cell** 139);
- The prediction of photoperiodic flowering regulators from gene circuit models (**Halliday** and **Millar** 2009, **Cell** 139) confirmed by experiments (**van Ooijen** and **Millar** 2012, **Science** 336);
- The development of a suspension culture of plant stem cells to produce biologically active compounds of medical importance (**Loake** 2010, **Nature Biotechnology** 28);
- Determination of the stochastic multistate nature of the bacterial flagellar switch (**Pilizota** 2010, **Science** 327);
- The demonstration that mammalian genes are transcribed with widely-different bursting kinetics (**Molina** 2011, **Science** 332);
- The discovery that circadian rhythms persist without transcription in a eukaryote (**van Ooijen** and **Millar** 2011, **Nature** 469);
- The demonstration that elastic domains regulate growth and organogenesis in the plant shoot apical meristem (**Nakayama** 2012, **Science** 335).

Integrating both 'wet' and 'dry' approaches is essential to our continued success in systems biology and our ability to grasp the exciting opportunity in synthetic biology. Our new academic staff are as likely to have qualified initially in physics, informatics or engineering as in biology, and we have successfully developed a culture to encourage continued communication across scientific borders. In the REF period we have made 8 strategic appointments to increase critical mass at the synthetic biology/biotechnology interface. These are **Cai** (CF, chromosome synthesis), **Granneman** (WT CDF, ribosome biosynthesis, £776k), **Horsfall**, (lectureship, microbial biotechnology), **Marles-Wright** (CF, integrative structural biology and signal processing), **McCormick** (CF, synthetic carbon cycle and photosynthesis), **Nakayama** (CF, synthetic morphology), **Pilizota**, (CF, bacterial osmoregulation) and **Wang** (CF, synthetic control circuits). We also have recruited **Rosser** (EPSRC Leadership Fellow) from the University of Glasgow to a Chair in synthetic biology, to take up her appointment immediately after the REF census date. Further, we have strengthened systems biology, from stochastic biology to evolutionary genomics, through the appointment of: **El Karoui** (Marie Curie fellowship and readership, single molecule imaging, £150k), **Grima** (SULSA lectureship, modelling stochastic processes, £350k), **Swain** (SULSA professorship, stochastic biology, £1M), **Molina** (CF, computational biology and evolutionary genomics) and **van Ooijen** (RS URF, circadian clock, £600k).

Interconnecting Themes These three Research Themes are also interconnected by a web of interactions facilitated by our culture of ready intellectual exchange, core equipment sharing and interdisciplinary research meetings. Current examples include the roles of small RNAs in infection; the links between structural biology, pathogen metabolism and drug discovery; epigenetic control of the immune response; stochastic modelling of DNA repair; and systems biology approaches to cell polarity, RNA metabolism and ribosome biosynthesis.

b3. Future strategic aims and goals In the next five years, we will sustain our support for excellence and innovation across all areas of research, developing our core capacity in **cellular**, **evolutionary** and **systems biology** to underpin future growth. In particular, we have ambitious plans to expand activities in the following specific areas: **epigenetics**, **synthetic biology and infection biology.** A major development and fundraising campaign is underway. External resources alongside University investment will be used to create new facilities and expand research staff and student numbers in these target areas.

Epigenetics is central to our vision. Although organisms retain their DNA sequences for life, epigenetic modifications can be changed. We aim to understand epigenetic mechanisms and learn how to influence them. This fundamental knowledge could enable interventions such as pharmacotherapy to fight disease, promotion of altered lifestyles to optimise healthy ageing, and strategies to improve food yields to feed a growing human population while using fewer natural resources in a warming climate. We will establish a **Centre for Epigenetics**, recruiting and bringing together new research groups with established staff (e.g. Bird, Allshire) and recent appointees (Bayne, Molnar) focused on epigenetic problems. We are already in the process of recruiting to a newly-established Chair of epigenetics and will make further early- and mid-career appointments to build critical mass. The new Centre will benefit from the facilities and expertise in our established Research Centres (WTCCB, CIIE and SynthSys) alongside significant new investment. The unique epigenetics capability that we are creating enables us to attract significant future support from government and charitable sources to grow new research programmes and establish world-leading facilities founded upon our pioneering development of this research area.

Synthetic biology underpins this ambition as it provides the conceptual and practical tools for advanced genome engineering, as well as the theoretical framework in which one can begin to investigate the most fundamental of epigenetic questions (what makes DNA live?). Application of new synthetic approaches to biotechnology promises to deliver health and economic benefits. The major hurdles in realising the benefits of synthetic biology are not in the creation and assembly of orthogonal parts; the real challenge lies in teasing out and engineering the intricate metabolic relationships between the synthetic construct and its host. These complex problems must be overcome to deliver the next leap forward, and we have crafted the right mix of expertise across disciplines that is required to achieve this integration of construct and host. The established SynthSys Research Centre already links biologists with engineers, computational and mathematical modellers, chemists, physicists, mathematicians and social scientists. Our strategic investment in new academic staff (Cai, Horsfall, Marles-Wright, McCormick, Nakayama, Pilizota, Rosser, Wang) has positioned us for dramatic progress in this area, which will be supported by our plan to increase strategic funding from government and industry. The establishment of IBIC is an important step linking synthetic biology to industrial biotechnology (see **b2 C** and **b4**).

Research in **infection biology** is vital to meet the urgent public health challenges presented by communicable diseases. We will extend our ability to understand the fundamental biology of infection, the intricate processes of the immune system, and the spectrum of remarkable strategies adopted by pathogens to invade and establish themselves in the mammalian host, and to provide insight into the evolutionary race between host and pathogen. Our work on pathogens will also reveal novel features of eukaryotic cell biology. By integrating expertise in each area, we are uniquely placed to harness this understanding to develop new, directed strategies to control both the susceptibility to infection at the level of individual hosts and the transmission of infection within populations at the global level. Strategic staff appointments during the REF period (Brown, Buck, Ivens, Obbard, Pedersen, Potocnik, Schnaufer, Spence, Szoor) have created a critical mass of researchers working at this interface area that is supported by the interactions and infrastructure of our Centre for Immunity, Infection and Evolution. This provides a platform to accelerate the translation of our fundamental science to therapeutic impact and diagnostic application.

b4. Responsiveness to national and international priorities and initiatives Research leading to **fundamental discoveries** is at the core of what we do. Our overall strategy is closely aligned with the priorities of key government funders, building from our base of original science to create capacity for target applications. We highlighted (in section **a**) three transformative breakthroughs arising from this fundamental research that illustrate our contributions in key priorities of both RCUK strategy and Horizon 2020: **Human health** and **food security**. Understanding the molecular basis of Rett syndrome unlocks the potential for curing the disease, also illustrating how reprogramming epigenetic control could lead to cures for other diseases. Understanding that the inflammatory response can utilise tissue-resident cells without the need for circulating blood cells changes our view of how to intervene in inflammatory processes ranging from wound healing to cancer. Determining how the plant biological clock functions will be important to maintain or improve crop yields in a changing climate, and thus enhance food security.

Our focus on infectious disease research directly addresses UK and international priorities such as the Grand Challenges in **global health**, including the rise of drug-resistant micro-organisms and the management and prevention of pandemics. For instance we co-direct the Scottish Interdisciplinary Centre for Human and Avian Influenza Research (Leigh Brown). Our Research Themes also overlap with the demands of government and global industries to develop new technologies such as greener materials synthesis and novel techniques for drug discovery. The expansion of **systems biology** has been a national priority and in 2007 we established CSBE with a 5-year non-renewable award (**b2 C**). From this established base we created SynthSys in 2012 to embrace the new strategically important direction of **synthetic biology**, a national research priority (one of the 'eight great technologies' identified by Minister David Willetts). Alongside **industrial biotechnology** (IB), a Scottish and UK priority area where we are partners with industry and other Scottish HEIs in an Innovation Centre (IBIC), these linked fields directly address the UK government and Horizon 2020 priorities of **resource efficiency and the bio-economy**. Our membership of SULSA (**b1**) has contributed significantly to our development of translational biology through the establishment of new protein production and drug discovery facilities, meeting global industry needs at a time when early-stage **drug discovery** is moving from the pharmaceutical industry to academia. We have also moved our stem cell biology closer to translation through the creation of the 'bench-to-clinic' research environment of the MRC Centre for Regenerative Medicine (**b1**), both meeting and setting the future agenda for Scottish and UK priorities in **regenerative medicine** (another of the 'eight great technologies').

b5. Development, promotion and dissemination of research

Strategic direction The Research Themes and Centres are represented on the **School Executive Committee** (chaired by the Head of School: Leach) and **School Research Committee** (chaired by the Director of Research: Allen), which have responsibility for overall strategy development and resource allocation. These committees include representation for postgraduate student matters and early-career researchers to ensure that research development needs at all levels are integrated into our strategic planning. Planning is facilitated by an annual 'away-day' for the senior management team, and by close liaison with the heads of other Schools and Colleges in developing cross-disciplinary opportunities.

Dissemination of research and communicating the impact of our science Our Research Themes are the foci for a vibrant research culture. Within each Research Theme, the members invite speakers for weekly external and internal seminar series (that are open to all) and for annual symposia. These are supported by devolved budgets to allow local decisions on research promotion and dissemination to be made. Each of our Research Centres holds an annual retreat and is advised by an international scientific advisory board. To promote interaction between Themes, we hold an **annual research symposium** for all academic staff, School-wide postgraduate poster days, and provide seed funding for initiatives that cross Research Theme boundaries. Our main research facilities and services are managed as School-wide facilities, providing resources and support for all researchers and promoting information exchange and knowledge sharing.

The School also provides funding for conference and workshop attendance and an open-access policy for publications. Early-career training (**c2**, **c4-5**) includes paper writing, scientific

presentation and communication with non-specialists. We also disseminate research through industry liaison and promoting initiatives that increase our impact (e.g. following on our success in winning the **2013 BBSRC Activating Impact Award**, we are leading the University of Edinburgh's entry to the **BBSRC's Excellence with Impact Competition**)(see REF3a).

Outreach activities We are committed to communicating the outcomes of our work to other researchers, opinion-formers and the general public. '**Research in a Nutshell'** videos provide one-minute video snapshots of individual researchers' work on our website. We produce a research podcast called **BioPod** that can be downloaded from our website or iTunes, which features in-depth interviews with researchers and round-ups of new findings and activities across our Research Themes. The podcasts are produced by a team of PhD students, who receive training and develop science communication and broadcast skills through their involvement. Over the last year, our podcasts have been downloaded 5,700 times by individuals from across the globe. The School's volunteer-run **Press Gang** supports the podcast team and provides an important interface between academic colleagues and the University press office. The Press Gang works to identify science stories of public interest across our Research Themes and to encourage and support their release to the media. Since its inception in 2002, the number of press releases we have produced that receive media coverage has increased from an average of 3 per year to 20 per year in 2012. These initiatives are complemented by a substantial programme of public engagement activities led by a public engagement coordinator and four dedicated science communication and public engagement staff (see REF3a).

Support for identifying and realising new research opportunities To support individual success, we provide mentoring and internal peer review for improving research proposals, workshops on funding opportunities and on grant writing, and start-up funding to new academic appointees to help establish their research programmes. We provide seed-funding for initiatives proposed by staff to establish new interdisciplinary and collaborative research activity and our Research Development Manager coordinates large-scale collaborative proposals.

Research support is delivered through our **Research Administration** and **Business Development** teams. Under the leadership of our Director of Professional Services, the 14 staff in our Research Administration team are responsible for grant costing and financial reporting, procurement and purchasing, managing staff contracts and research student procedures, and advising on proposal and grant management. We employ three **Business Development Executives (BDEs)** with expertise in commercialisation and knowledge transfer. They work as part of the University's commercialisation arm, **Edinburgh Research and Innovation (ERI),** to provide the most appropriate support for researchers in identifying, protecting and developing IP assets, fostering partnerships with industry, securing follow-on funding, and enabling licensing, consultancy and company formation. Having our Research Administration and Business Development teams embedded within the School ensures that they are integrated with our research structures and guided by our strategy. They also understand, and are actively responsive to, the scientists' needs and timescales.

c. People

Our research success is critically dependent on the creativity of our staff and students, and we strongly promote opportunities for them to fully develop their potential.

c1. Staffing strategy We have set out in section **b2** how our appointments during the REF period have been targeted to deliver our research strategy. This staffing strategy has led to a balanced age profile including a substantial number of early-career staff, many with tenure-track appointments, representing a major investment in the future of the discipline (Table 1).

Table 1 Academic staff age profile

Age range	25-35	36-45	46-55	56-65	>65
Proportion of academic staff	23%	30%	30%	15%	3%

The University will make 50 new Chancellor's Fellowships available in 2014, of which biological sciences expects to secure at least 3. This is part of the University's mission to be the UK's leading institution in supporting the development of early-career academic staff and ensuring the sustainability of our science.

c2. Staff development and support All new members of academic staff receive a coordinated induction programme with both a School-specific and University-wide component (the latter through the **Institute for Academic Development**, **IAD**, which provides professional development and support for research and teaching). Each new staff member is allocated one or two **academic mentors** who provide guidance and support through the transitional period of setting up a research group and help new staff to develop a successful independent academic portfolio of work and skills. Staff members at all levels have annual reviews (performance and development) with their line manager. We also hold an annual senior management meeting at which all academic staff are reviewed for promotion or contribution reward. A **workload model** provides transparency in balancing teaching, research, administration, knowledge exchange and wider academic contributions. Newly-appointed staff members have reduced teaching and administration loads to facilitate the establishment of successful research programmes. A wide range of **development opportunities** and training for academic roles is provided by the University, to which we direct our research staff and academics at different career stages, from postdoctoral to senior leadership. We offer training in public engagement through the University's Edinburgh Beltane network and in commercialisation and entrepreneurship through ERI. We also support staff to take up external opportunities such as the EMBO group leader course.

To support research from proposal to dissemination of outcomes, a School team of 82 technical/computing staff and 36 administrative staff provides research computing, laboratory support, small to large research facilities, and services for safety, research administration (proposals and awards, purchasing, students and staffing), outreach and commercialisation. By providing this support locally, it can be most responsive to the needs of researchers. The University provides other research services centrally, including excellent high-performance compute and data facilities.

c3. Equality and diversity Equality issues are monitored and championed by a School E&D Committee; the convenor (Hudson) is a member of the School Executive Committee. Our overall research staff profile includes 30 different nationalities and is 45% female. We created a formal action plan for E&D in 2012. We have a default policy of accepting all reasonable requests for flexible working or other adjustments. Our success in promoting equality is illustrated by a professoriate that is 23% female, significantly higher than the national average for biology. We have increased the representation of women on our senior strategic committees from 10% to 36% over the REF period (equivalent to the proportion of women academics in the School). Our implementation of policy and practice to promote gender equality has been recognised by an **Athena SWAN Silver Award** to the School in April 2013.

c4. Early-career researchers and contract research staff In 2010 we created a society for early-career scientists (**BioDocSoc)** that spans the postdoctoral and PhD student communities. This is now self-organising and runs scientific, social and training events including a technical expertise exchange forum and a forum specifically for discussion between postdocs and School management. We also introduced a process to increase retention of researchers between projects; annual turnover amongst postdoctoral research staff has subsequently decreased from 22% to 13%, providing better career stability and retaining key skills. We endorse the **UK Concordat to Support the Career Development of Researchers**, operating our own Code of Practice in line with its principles. The University gained the EC **HR Excellence in Research Award** in 2010, recognising our implementation of the principles of the European Charter for Researchers.

In 2011, we launched a formal '**New Research Leader'** programme for new academic staff, run in collaboration with IAD. This four-day course covers research planning and management, people management and personal development. Because our staffing strategy relies strongly on the recruitment of independently-funded research fellows, we have instituted a comprehensive **Fellowship Review and Retention** policy. Fellows are offered a development review after 2-3 years, and on award of a second or renewed fellowship are reviewed for transfer to a University-funded position after the cessation of fellowship funding, based on performance and fit to our strategic priorities. In the REF period 10 fellows have been transferred into open-ended academic posts, and a further 9 current fellows have received undertakings for future transfer.

c5. Research students Our portfolio of studentship funding offers a wide choice to prospective

students and we recruit an average of 60 PhD students per year. We are the lead department for the largest **BBSRC Doctoral Training Partnership (DTP), EASTBIO**, awarded in 2012. This £6.8M postgraduate research training partnership brings together the Universities of Edinburgh, Dundee, St Andrews and Aberdeen. EASTBIO awards 16 studentships per year at the University of Edinburgh, with 6-7 of these awarded in UoA5. Currently 7-8 studentships per year are funded by **MRC, NERC** and **EPSRC.** 6 **SULSA BioSKAPE** studentships (BBSRC/SFC/industry funding) support cross-institutional and industry-linked projects; in addition, we award 1-3 **Industrial CASE** studentships per year. During the REF period we have run two **WT 4-year PhD programmes,** in the cellular and molecular basis of disease (until 2012) and in cell biology (2008-present) and have hosted a **Marie Curie Early Stage Training Network** in genomics and the analysis of complex traits (until 2010). We typically secure 10 international studentships per year funded by **The Darwin Trust of Edinburgh**. Around 20 students per year are self-funded, attracted by our research and training environment, or are supported by overseas governments, charitable or industrial scholarships or by individual supervisors' resources. The University provides targeted scholarship programmes for selected countries, and the School directly funds 10-15 PhD studentships per year, often matching partial funding from external sources to enable us to recruit the best students regardless of means. We also run collaborative PhD programmes with **Scotland's Rural College (SRUC)**, the **Royal Botanic Garden Edinburgh (RBGE)**, and the **James Hutton Institute**, and jointly supervise students with staff in chemistry, engineering, informatics, mathematics, medicine and physics. All PhD students are selected through the same rigorous panel interview process. Typically 60% of our PhD students are from overseas and 57% are female, which is higher than the UK average for biology (see also **c3**).

All postgraduate research students are members of the **Graduate School of Biological Sciences** and members of BioDocSoc (**c4**). The Graduate School Committee, led by the Director of the Graduate School (Stancheva), ensures effective milestone monitoring and progression support across our programmes. Supervision and training quality is overseen by the Graduate School Committee and by a thesis committee for each student, consisting of their primary and secondary supervisors and one or two independent academics. Key events on the path to a PhD are an assessed written report and viva for all first year students, presentations by second year students at an annual Graduate School Poster Day, and a seminar given at a Final Year Symposium. Our 4-year completion rate for students starting between 2006 and 2009 averages 82% (and would be even higher if adjusted for part-time study and approved suspensions). Our most recent survey of first destinations found that 84% of our graduates went on to research careers in industry or academia.

The Graduate School, working with the IAD, provides core PhD training courses and events that integrate transferable and scientific skills. In addition to training in research ethics, project management, writing papers, conference presentations and thesis writing, we have established specialised training in core bioscience skills, including statistics, experimental design, bioinformatics and in key technologies including flow cytometry, advanced optical imaging and genome manipulation. EASTBIO implements a **PIPS (Professional Internship for PhD Students)** scheme in which students undertake a three-month work placement to develop non-research experience and skills. The **Principal's Career Development Scholarships** provide the opportunity for some students to develop deeper skills in teaching, public engagement, or entrepreneurship as part of their doctoral studies. The **Launch.ed** programme provides direct commercialisation advice and support to students wishing to develop IP from their research, complementing the support available from our Business Development Team. This is particularly, but not exclusively relevant to our CASE-funded studentships, in which students have worked with established pharmaceutical and agri-biotech companies or smaller SMEs. IAD also provides students with broader training opportunities covering all areas of the **Vitae Researcher Development Framework.**

d. Income, infrastructure and facilities

d1. Research income Over the REF period we have attracted £154M in research grants and contract awards (£69M CSB, £67M EII and £18M SSB). The distribution of award value reflects the well-established profile of our CSB and EII Themes and the developing success in our new, rapidly growing, SSB Theme. Expenditure (income) over the REF period is £122.2M (£52.3M CSB,

£51.5M EII and £18M SSB). Our research award portfolio thus ensures we have a healthy funding base for continued research expenditure beyond the REF period. 26 research grants awarded during the period have been between £1M and £2M, and 14 grants over £2M in value. These include the £5M renewal of WTCCB (2011) and a £2.4M WT strategic award to support CIIE (2011). £5.5M of funding comes from schemes targeted to translate fundamental discoveries into applications, including BBSRC Sparking Impact, MRC Developmental Pathway Funding Scheme, WT Seeding Drug Discovery and the Technology Strategy Board. Not included in the total award figures are the SFC IBIC funding and our WT Institutional Strategic Support Fund (ISSF) of £2M per annum (since 2011).

d2. Research infrastructure and facilities Enhancing our infrastructure and facilities has been a critical component of our overall research strategy (**b**), with over £20M invested during the REF period. Co-investment through pooling of resources across HEIs has enabled wider benefits and relates directly to collaboration (**e**).

Estate We are actively engaged in a programme of estate development and expansion. The new £7M 'CH Waddington' Building opened in 2009, to house systems biology and chemical biophysics. We are partway through the refurbishment of the 'Ashworth Two' Building, to house the CIIE and the Edinburgh Genomics sequencing facility; two floors have been completely renovated and the remaining three floors will be complete by 2015 (£9.5M total including £1M from the Wolfson Foundation). Stem cell research (now in UoA1) relocated to the new Scottish Centre for Regenerative Medicine building in 2011 (£54M). Synthetic biology and biotechnology will move in 2015 to newly-refurbished accommodation currently being prepared (£7M). A £60M+ estate development programme is underway to provide state-of-the-art new facilities for epigenetics, cell biology expansion and further synthetic biology capacity, along with outreach, commercial and research interaction space; we have already secured a lead donation of £5M (Darwin Trust) towards this ambitious programme.

Facilities **Genomics:** Edinburgh Genomics is one of the best-equipped next-generation genomics and bioinformatics facilities within any UK university. Edinburgh Genomics was formed from the merger of two successful, existing facilities (GenePool and ARK-Genomics) in 2013 with Blaxter appointed as director. Edinburgh Genomics is a recognised component of UK national capability in genomics with NERC (the NERC Biomolecular Analysis Facility) and BBSRC, and is also one of two MRC High Throughput Sequencing Hubs (£5.3M external awards and £1.3M University equipment investment during the REF period). The facility supports research from conception, through grant application, execution, analysis to publication, and has an important role in training in use of new data and tools. The facility has been instrumental in introducing new genotyping-by-sequencing approaches to the UK science community. The facility has six Illumina HiSeq2500, three MiSeq, robotics and high performance computing (0.25 Pbyte storage, 500 cores of HPC compute with >8 Tb RAM), supported by 19 technical staff and 7 bioinformaticians. **Proteomics:** The Kinetic Parameter Facility (KPF) develops and deploys quantitative mass spectrometry to study protein composition, protein modification and protein-protein interactions. The facilities include 5 Orbitrap mass spectrometers. The KPF has been supported by £2.2M BBSRC/EPSRC and Wellcome equipment and staff funding during the REF period. **Protein production and biophysics:** The Edinburgh Protein Production Facility (EPPF) and biophysical characterisation suite provides state-of-the-art equipment and expertise for rapid protein production including high-throughput robotic crystallisation, cloning and screening facilities. It offers equipment for X-ray diffraction, isothermal titration calorimetry, surface plasmon resonance, NMR, light scattering and fluorescent spectroscopy (£2M Wellcome, SULSA and University funding). Our integrated chemical biophysics platform (£0.9M University investment) enables development and application of miniaturised, ultra-high throughput screening for the identification and validation of lead compounds for drug discovery and tool compounds for basic research. The platform combines chemical, biological, and physical approaches, using flexible post-synthesis, post-screening, tagging technologies and combining label-free and single molecule fluorescence detection technologies into seamless processes. **Robotics**: A high-throughput suite set up with £0.9M initial University investment enables high-quality rapid screening (e.g. of yeast strains carrying a systematic deletion collection, or cultured cells treated with banks of small molecules). An Opera spinning-disk confocal microscope allows fast scanning in multiple wavelengths, sections, and fields and over time. Two liquid handling robots assist with sample preparation and automatic

reloading, with multiple plate readers available for kinetic studies and a robotic system for handling cultures of microorganisms. **Optical Imaging:** Our Central Optical Instrumentation Laboratory (COIL) houses state-of-the-art light imaging equipment including deconvolution, fluorescence and confocal microscopes. Recent ISSF investment has enhanced our optical microscopy facilities for biophysical manipulation of cells in microfluidic devices and the live-cell imaging of single molecules (£0.5M University/Wellcome Trust investment). **Electron Microscopy**: COIL also manages our electron microscope facilities, which include scanning electron microscopy and transmission electron microscopy. In 2010 we set up a cryo-electron microscope (cryo-EM) facility capable of rapid, high-resolution data collection of single macromolecules in their native hydrated state (£1.3M Wellcome and SULSA funding). **Animal and plant facilities**: We have 1500m^2 of facilities for rodents, fish, birds, insects and amphibians, supporting animal model research in development and disease, vector-borne infectious disease studies, and behavioural research. 1000m^2 of controlled-environment plant growth and glasshouse space provides facilities for plant cell, systems and synthetic biology, natural product development and evolutionary genetics, including high-specification darkrooms for circadian clock research.

d3. Sharing of infrastructure and facilities All **SULSA Facilities** are available at cost to all SULSA universities. We run three of these facilities (Edinburgh Genomics, EPPF and cryo-EM) and we have access to all the other SULSA facilities (high throughput structural proteomics, metabolomics, imaging and drug discovery facilities, micro- and nano-fabrication and mouse transgenics. The **Edinburgh Super-Resolution Imaging Consortium (ESRIC)** was formed in 2013 as an alliance between the University of Edinburgh and Heriot-Watt University to facilitate super-resolution imaging. This consortium offers atomic force microscopy, PALM, STORM, GSDIM, structured illumination and gated STED (£2M funding from MRC). **UK National Facilities**: we have a 2-year rolling access award from STFC for time on Diamond synchrotron.

d4. Benefits-in-kind SULSA has secured £80M in-kind support from participating companies, alongside £20M from the Innovative Medicines Initiative and Scottish Government, in the European Lead Factory drug discovery facility at BioCity (managed for SULSA by the University of Dundee).

d5. Research governance The University has adopted **UKRIO policy** on good practice in research. The Head of School has overall responsibility for research governance, supported by our team of professional administrative staff and by University specialist advisors. Our local policies ensure compliance with wider University and legislative frameworks for safety, ethics, data security and research practice & management, with a particular responsibility placed on academic staff to lead good practice in their research teams. We have an academic ethics advisor and a full-time professional safety advisor. The University's internal audit undertakes periodic review of all areas of our business, to provide assurance that our governance is effective.

e. Collaboration and contribution to the discipline or research base

Our structures and strategy are designed to enhance collaboration. We create influence through supporting and shaping the discipline and we promote this by recognising such contributions in staff workload and reward processes.

e1. Interdisciplinary research Interdisciplinarity is at the core of our research strategy and collaboration is key to its delivery. Our three Research Centres (**b2**) are designed to facilitate this. Over and above this, we are engaged with several other interdisciplinary Research Centres and groupings in the University of Edinburgh. These include the **Centre for Translational and Chemical Biology** (**CTCB**; Director Walkinshaw) which links us closely with chemistry; the **Centre for Science at Extreme Conditions** (**CSEC**) with physics, chemistry, geosciences and engineering; and the **Collaborative Optical Spectroscopy, Micromanipulation and Imaging Centre** (**COSMIC**) with physics. The **KingsLinks** programme of postdoc-led colloquia (initiated by Allen in 2012) successfully generates discipline-crossing grant applications between biology, physical sciences and medicine across two campuses.

e2. Collaboration beyond the University of Edinburgh Our interdisciplinary collaborations extend beyond the University. **Edinburgh Infectious Diseases** (**EID**; convenor Maizels) provides a network for biological, medical and veterinary researchers in infectious disease from organisations around the city. Two new networks on the same model have been created in 2012-

13: the **Edinburgh Ecology Network** (**EdEN**; co-coordinators Stone, Phillimore), a city-wide ecology research forum encompassing biologists, geoscientists and economists; and the **Edinburgh Alliance for Complex Trait Genetics** (**E-ACTG**; co-founder Pemberton) which links biologists, clinicians and agricultural researchers involved in quantitative genetics research.

We are founding members of **SULSA** (**b1**). We host its administrative offices and have played a major role in its establishment and development, including directing two of the three SULSA research strands when first established (Leach, Millar), providing the first SULSA Director, Tyers (who has since moved to Montreal) and the current director of the Cell Biology strand (Finnegan). In particular, we helped shape the policies and practices of shared facilities (**d3**) and joint studentships crossing institutions (**c5**). Other significant UK collaborations include **EASTBIO** (**c5**), **IBIC** (**b2 C, b3** and **b4**) and the **Flowers Consortium** (**b2 C**). We lead an initiative to develop closer collaboration between Wellcome Trust-funded Centres in Scotland, and organised the inaugural **Wellcome Trust Joint Centres** Scottish Excellence meeting in 2012.

Our leadership of national and international collaborative research programmes during the REF period includes: **Ribosys** - Beggs coordinated the EU FP6 *Systems Biology of RNA Metabolism in Yeast* project, 8 research groups in 6 countries; **ROBuST** - Halliday leads the BBSRC/EPSRC *Regulation of Biological Signalling by Temperature* project, 6 research partners across the UK; **TiMet** - Millar coordinates the FP7 project *Linking the Biological Clock to Metabolism*; **NERC long-term studies** - Pemberton & Kruuk coordinate two long-term population and genetic studies (Red Deer on Rum and Soay Sheep on St Kilda) in conjunction with Cambridge, Imperial College, Sheffield and the Hutton Institute. We have been partners in many other European (FP6 and FP7) projects during the period (not listed here for reasons of space). We also have strategic links with scientists in disease-endemic countries (e.g. Zimbabwe, Kenya, Brazil, Cameroon), notably with the **Busia field station** in Kenya, which we co-fund and which currently hosts three of our postgraduate students.

e3. Influencing and supporting the discipline For reasons of space we have not noted here the extensive contributions through journal editorships (of 40 different journals), membership of peer review colleges, national and international review panels and editorial boards, nor the participation in conference organizing and invited/keynote talks at national and international meetings, all of which we take to be expected of our academic staff. Exemplars of more strategic roles during the REF period are illustrated under selected headings.

Governorships and senior office bearers **Beggs:** Vice-President for Life Sciences, RSE. **Bird:** Governor and Deputy Chairman of the Wellcome Trust. **Finnegan**: Chair, Sub-panel D14 for RAE2008. **Gray:** General Secretary of the British Society for Immunology and Chair of the Board of Trustees. **Pemberton** succeeded by **Ohkura**: Treasurer, Genetics Society. **Sharp**: President, Society for Molecular Biology and Evolution.

Leadership of international and national research consortia **Blaxter**: International Nucleotide Sequence Database Consortium Steering Group. **Leigh-Brown**: UK HIV Drug Resistance Database Executive Committee and Chair, Molecular Epidemiology Study Group. **Loake**: India-Scotland Joint Plant Science Programme Committee. **Millar**: UK representative on the Multinational *Arabidopsis* Steering Committee and co-chair of Systems Biology sub-committee; Co-Chair of Banbury global working group on an international model for plant science; Coordinator of GARNet, the functional genomics network of 120 UK laboratories studying the plant *A. thaliana*.

International and national advisory board membership **Allen**: SAB for the Institute of Life Sciences, Bhubaneswar, India. **Arnot**: SAB, European & Developing Countries Clinical Trials Partnership. **Beggs**: Manchester Interdisciplinary Biocentre SAB; Max F. Perutz Laboratories, Vienna SAB. **Bird**: Science Planning Committee of the UK Centre for Research and Innovation. **Blaxter**: SAB of the European Nucleotide Archive; SAB of the Metagenomics Portal Project of EMBL-EBI; SAB of WormBase, the international *C.elegans* genome database; SAB of BBSRC TGAC, Norwich. **Ennos**: UK Joint Panel on Plant Genetic Conservation. **Finnegan:** UK REF2014 EAG; chair of Biology Panel, Hong Kong REF 2014. **Gray**: Expert Advisory Group (Rheumatology & Immunology) to the Commission on Human Medicines. **Millar**: International SABs for Plant Structural Modelling (John Innes Centre) and DFG GoForSYS project; member of the BBSRC Expert Working Group on Digital Organisms; international review panel, Okinawa Inst of Science &

Technology. **Pemberton**: SAB for Max Plank Institute for Evolutionary Biology.

Committee membership of professional bodies, charities and trusts **Allshire**: RSE Sectional Committee A4; RS Sectional Committee 6. **Beggs:** EMBO Conferences and Workshops Committee; RSE Vice President for Life Sciences; RS Nominations Committee; Trustee of the Darwin Trust. **Bird**: Trustee and Chair of Research Strategy Committee at CRUK; Trustee of the Kirkhouse Trust, Scotland; Trustee of the Rett Syndrome Research Trust, USA. **Colegrave**: Fund for the Replacement of Animals in Medical Experiments Steering Committee. **Earnshaw**: Chair, EMBO Course and Conference Committee. **Finnegan:** Trustee of the Darwin Trust. **Leach, Pemberton** and **Sharp**: RSE Sectional Committee A4. **M Taylor:** British Society for Immunology early-career representative. **Tollervey**: Wellcome Trust Expert Review Group 8; RS Sectional Committee 6; RSE Sectional committee A4.

Membership of grant and fellowship awarding bodies **Allen**: MRC Infections & Immunity Board; ERC panel LS6 Immunity and infection; Wellcome Trust Basic immunology and infectious disease funding committee. **Allshire**: Wellcome Trust Basic Science Interview Committee; Wellcome Trust/ RS Sir Henry Dale Interview Committee; RS Newton International Fellowship Committee Biological Sciences. **Auer**: Member of the Jury, French National Research Agency INRA. **Beggs**: RS B-side Awards Committee; Board of Electors to the Iveagh Professorship of Biochemistry, U. Oxford. **Blaxter**: SYNTAX funding committee (NERC/BBSRC/Linnaean Society). **Böttcher:** Academy of Finland Bio Panel. **Earnshaw**: Sir Henry Wellcome Postdoctoral Fellowship Interview Committee. **Ennos:** NERC Standard Grant and Fellowships Panel. **Finnegan:** MRC Molecular and Cellular Medicine Board. **Hardwick**: CRUK Studentships Award Committee. **Hudson**: BBSRC Committee B member. **Loake**: *Ramon y Cajal* tenure track appointments committee to Spanish Universities. **Matthews:** Wellcome Trust Public Health and Tropical Medicine Interview Panel. **Millar**: BBSRC Enhancing Photosynthesis Initiative Panel. **Pemberton**: Zoological Society of London Awards Committee. **Reece:** NERC Standard Grant and Fellowships Panel. **Richardson** and **Spagnolo**: Institut Laue-Langevin Biology Subcommittee. **Tollervey**: RS University Research Fellowship Committee B. **Zamoyska**: HFSP grant review committee; ERC starting grant panel (immunity & infection).

Honours, fellowships and other awards Our faculty includes 7 **FRS**, 16 **FRSE**, 1 **RSE Young Academy** member, 8 **EMBO** members, and 2 **CBE**.

During the REF period, honours awarded include: **Allshire**: FRS; Genetics Society Medal. **Bird**: Charles-Léopold Mayer Prize; Gairdner International Award; RS GlaxoSmithKline Prize; HonDSc (Sussex). **Cai**: iGEM Gold medal and Best software award; Autodesk Distinguished Scholar; GSA DeLill Nasser Award. **Collins**: IMF-Geomar Petersen Professorship. **Earnshaw:** FRS; Fellow, Academy of Medical Sciences. **Jeyaprakash**: Max Planck Institute of Biochemistry Junior Research Award. **Kruuk**: Zoological Society of London Scientific Medal; FRSE. **Leach:** FRSE. **Little**: Zoological Society of London scientific medal. **Loake**: Honorary Professor, Institute of Genetics & Developmental Biology, Chinese Academy of Sciences. **Marston**: EMBO Young Investigator. **Matthews**: British Society for Parasitology C.A. Wright Medal. **Millar**: FRS; FRSE; Saltire Award; elected to EMBO. **Mutapi**: RSE Young Academy. **Nagy**: member of EMBO Council; corresponding member of the Hungarian Academy of Sciences; Member of the German Academy of Sciences. **Pemberton**: FRSE; *Molecular Ecology* Prize. **Rambaut**: Zoological Society of London Scientific Medal; Senior Visiting Research Fellowship, US National Institutes of Health; International Society for Bayesian Analysis Mitchell Prize. **Reece**: NEXXUS East Young Life Scientist of the Year; L'Oréal-UNESCO Fellowship for Women in Science. **Sharp**: FRS; FRSE. **Spoel**: New Phytologist Tansley Medal. **Tollervey**: HonDSc (University Paul Sabatier, Toulouse).

Research fellowship awards 87 externally-funded research fellowships have been held during the REF period. These include: 3 WT Principal Research Fellows; 1 RS Professorial Fellow; 14 Senior/Advanced Fellows with funding from MRC, WT, NERC, CRUK and EU; 42 'Career Development' and other standard-level fellowships (WT, MRC, NERC, BBSRC, EPSRC, RS, EU and other charities); 13 RS University Research Fellows; and 14 sponsored training fellowships (WT, EU, RS and other charities). More than 50 of these fellowships were awarded or renewed during the REF period, with a total value of £45M.