Institution:
University of Exeter

Unit of Assessment: 5

a. Overview

We have transformed Exeter Biosciences since RAE2008. 33 new academic staff have been appointed to five interlinked research groups at our Exeter (Streatham) and Cornwall campuses. Building on 38 appointments made in the previous RAE period, biological research at Exeter has embraced rapid changes in the discipline, with an increasing emphasis on quantitative systems biology and applying evolutionary approaches to ecological questions. Our five research groups comprise three based in Cornwall: *Behaviour*, *Ecology & Conservation* and *Evolution*; plus two at Streatham: *Cellular & Chemical Biology* and *Microbes & Disease*. These groups interact extensively across campuses and Biosciences also has significant research activity in *Environmental Sciences* (returned to UoA7). Here, we include only appointments, income and publications relating directly to our UoA5 groups, but they should be recognized as operating within a larger grouping of staff within the interdisciplinary College of Life and Environmental Sciences.

b. Research strategy

Biosciences is now the largest research grouping at the University of Exeter, employing 72 FTE academic staff, 95 technical and administrative staff, 91 postdoctoral researchers and 150 PhD students. Continued growth of Exeter Biosciences is central to the University's Science Strategy, launched in 2008. We have exceeded growth plans set out in RAE 2008 (see Section c), and will grow by a further 30% over the next three years to 95 FTE academics. This growth has been sustained through expansion of research income and undergraduate recruitment. Expansion has been matched by improved quality; Exeter Biosciences has rapidly risen in league table rankings, based both on research and teaching quality, rising 22 places in the Times league table since 2008 and 18 places in the Guardian national league table where it currently ranks 4th. In the Leiden rankings, based on the most recent (post-2008) citation data, Exeter Biosciences was ranked 4th in Europe. Our research awards have risen at a similarly rapid rate, rising from £6.8m awards won in 2009/10 to £16.9m in 2012/13.

Development of the research environment

The central aim of Biosciences is that each of its research groups should aspire to be in the very top echelons of their field worldwide. To accomplish this, we have invested in new academic staff and infrastructure detailed below. We have also appointed a core of teaching staff which has enabled us to achieve a 20% reduction in mean teaching contact hours of research-active staff since 2008. At the same time, we have improved support for academic colleagues in grant capture, by appointing five research support officers, dedicated to biological research, in our Research and Knowledge Transfer (RKT) division. Alongside this we have increased our complement of general administrative support staff, adding seven positions. All of these initiatives have significantly reduced the overall teaching and administrative workload of our research-active academic staff.

Investment in infrastructure

At Streatham we have invested £26m in refurbishment of our main seven-storey Biosciences facility (The Geoffrey Pope Building). The 4,817 m^2 of lab space has been re-furbished to BSL2 and BSL3 standard. In addition to modern, purpose-built laboratories we invested in specialist facilities, including high throughput sequencing (Illumina HiSeq 2500 & MiSeq), Wolfson Foundation fudned bio-imaging facilities (Confocal laser scanning, SEM and TEM), LC-MS and uniquely in a UK university, a £9m 600 tank aquarium.

At the Cornwall campus we have made a £30m infrastructure investment in the interdisciplinary *Environment and Sustainability Institute* (ESI). The ESI includes bioscience labs, totalling 460 m^2. It also houses a proteomics suite; facilities for stable isotope analysis, microscopy, microbiology and molecular biology. More than £2m of equipment has been purchased to support these labs. There are eight fully programmable 12m^2 climate controlled rooms (designed with a very low carbon footprint), allowing us to conduct highly controlled and replicated experiments on invertebrates, plants and small ecosystems. The ESI building also houses laboratories of the European Centre for Environment and Human Health (ECEHH), which includes significant new research on environment-related disease and impact of medical treatments on the environment.

We have also converted existing buildings at Cornwall to expand into a further 16 academic staff offices and write-up space for 15 final year PhD students. A new £5m Biosciences building, linked to existing facilities, will also commence construction in spring 2014, with new laboratories for evolutionary biology and conservation research.

We have just embarked on a major infrastructure project to build a new 7500m^2, £50m interdisciplinary *Living Systems Institute* on the Streatham Campus, directly linked to the Geoffrey Pope laboratories. This facility will open in Spring 2016 and bring together mathematicians, cell biologists, physicists and engineers into a single facility aimed at studying living organisms as integrated, dynamic systems. A total of 30 new academic appointments will be made (at least eight in Biosciences) working on experimental and predictive aspects of the cellular and molecular basis of disease, particularly in the context of environmental change.

Biosciences and the University Science Strategy

The University of Exeter embarked on an £8m Science Strategy in 2008, with a further £2.5m in new posts invested in 2010, across five interdisciplinary research themes. Biosciences leads the interdisciplinary **Systems Biology Theme**, involving investments of £3.35m from the University to fund eight new Biosciences staff (Rob Beardmore, Angus Buckling, Richard Chahwan, Michael Deeks, Ivana Gudelj, Ken Haynes, Gero Steinberg and David Studholme) and £516K towards PhD students focussed on using informatics, modelling, proteomics, genomics and metabolomics to understand problems ranging from pathogenesis of plant and human infection, to the organisation of ecosystems. Research within the theme seeks to integrate different hierarchies of biological information such as DNA, RNA, proteins and small molecules to provide new insight into the organisation and operation of macromolecular complexes, cellular signalling networks, cells, organs or whole organisms. Since 2008, 24 Biosciences staff within the Systems Biology theme have published 608 papers, graduated 40 PhD students and brought in £28.5m in external grant funding. We also contribute strongly to the **Climate Change & Sustainable Futures Theme**, which brings together researchers from across disciplines to combine environmental, economic, physical and mathematical approaches to what is one of the most pressing issues of our century. This theme is detailed in our UoA7 return and has also allowed us to strengthen the Ecology and Conservation group through funding appointment of Frank van Veen, coupled to provision of PhD studentships supervised by UoA5 staff studying biological influences and consequences of climate change.

Research plans: Future growth

Our plans for further growth reflect a strong commitment by the University to interdisciplinary research underpinned by continued central investment in thematic programmes, which aim to build links both within and between the six interdisciplinary Colleges of the University. Biosciences, for instance, has extensive links to geographers, sports scientists and psychologists within the College of Life and Environmental Sciences, studying climate change, physiology and animal behaviour, respectively. In addition very strong links have been built with the Exeter medical School and mathematicians, computer scientists, physical chemists, and physicists in the College of Engineering, Maths and Physical Sciences. Future hiring plans are formulated within this interdisciplinary context, linked to over-arching Science Strategy themes of the University. In this way, we have developed a clear strategic plan to develop each of our five research groups:

1. **Cellular & Chemical Biology** and **Microbes & Disease** – We will hire 12 new staff, including eight in 2016/17 to be housed in the Living Systems Institute, with a focus on the systems-level understanding of disease and infection.
2. **Behaviour** and **Evolution** – We will hire five new staff in evolutionary approaches to infectious disease evolution and genomics, expanding strengths in wildlife disease but also including evolutionary approaches to understanding human diseases such as HIV, housed in the new £5m extension of our Cornwall laboratories.
3. **Ecology & Conservation** – We will hire two further staff in conservation, with a focus on marine resources, and a further two UoA7-facing appointments in ecotoxicology and ecosystem responses to climate change.

These appointments and associated infrastructure will increase capability and capacity, strengthening our NERC and BBSRC income and widening our portfolio of funding streams to target new opportunities from the MRC and Wellcome Trust. Appointments in Evolutionary Biology

of Disease at the Cornwall Campus link to the ECEHH and the University of Exeter Medical School, which has rapid development plans for the next five years. We will also continue to build and augment strategic partnerships with outside organisations, such as our extensive links to Rothamsted Research (food security); Shell Research (biofuels), Defence Science and Technology Laboratory (Dstl) (infectious diseases) and Syngenta (plant health). Since 2010, we have signed strategic agreements with all three of Defra's science agencies: the Food and Environment Research Agency (Fera), the National Wildlife Management Centre of the Animal Health and Veterinary Laboratories Agency (AHVLA) and the Centre for Environment, Fisheries & Aquaculture Science (CEFAS). Since 2008, we have built active research partnerships with these organisations, principally undertaking applied research in the areas of environmental health and management. UoA5 staff have initiated projects on bee disease, bat rabies, assessment of new techniques for evaluating the impact of biodiversity on human health and a significant programme of projects on the epidemiology of tuberculosis in badgers. As an example of the success of these agreements since 2008, the National Wildlife Management Centre (AHVLA) and Exeter Biosciences have jointly supported 27 postgraduate research studentships (14 PhD & 13 Masters by Research), and a postdoctoral fellowship.

Responsiveness to national and international priorities

Our commitment to responding to external research priorities is reflected in grants we have received through specific calls. For example, we secured a £4m BBSRC LoLa on engineering synthetic microbial communities for biomethane (Titball and Buckling) a £1.2m BBSRC-BBR grant on functional genomics of *Mycosphaerella graminicola* (Haynes, Studholme, Talbot, Steinberg) a £2.0m BBSRC-SCPRID food security grant to develop durable resistance to rice diseases in sub-saharan Africa (Talbot) and we were part of the £2.4m BBSRC–NORNEX taskforce funded in 2013 to address Ash Dieback disease (Gurr, Talbot, Studholme, Steinberg).

Evolutionary biology research has also been applied to specific priorities, such as Angus Buckling's AXA funded (£350K) project on social evolution of bacterial heavy metal bioremediation. The strategic alliances with FERA and CEFAS, and strong links with Dstl have been motivated by a desire to target research at areas of national concern. We also aim to build additional links to organisations in the South West to help stimulate economic activity in the region. This is the major goal of our new Environment and Sustainability Centre, and Rick Titball and Nick Smirnoff are Science Champions for the Exeter Science Park, which opened in 2013. We are succeeding in our mission to embed a culture that recognises the importance of economic and social impact, as reflected in our runners-up position in the 2012 BBSRC *Excellence with Impact* awards.

Promotion and dissemination of research

We have issued 140 press releases, including posting on Facebook and Twitter, and we have recorded >3000 pieces of media coverage since 2008, and Exeter's YouTube channel hosts video features on our research. We have an informal 'press gang' that involves PhDs and PDRAs in disseminating research and organising media training. Examples of media coverage include the 2010 BBC2 series *'Banded Brothers'* about Mike Cant's study of banded mongooses seen by a global audience of >20m. Nick Smirnoff contributed an experiment to BBC2's *'How to Grow a Planet'*; David Hodgson made several national TV appearances in 2013 for his work on animal navigation and Stuart Bearhop's work has been featured on both '*Autumnwatch'* and '*Springwatch'*.

Developing and maintaining an active research culture

Our priority in establishing a vibrant research culture has been to ensure that all research-active academic staff are motivated and supported to develop as researchers. Early career researchers always have a teaching-free period upon appointment, and a very reduced teaching load during the first three years of appointment. The success of this was recognised by award of the Scopus Fostering Great Research Award, based on the university having the highest UK citation index for newly appointed staff. PhD studentships funded through quota, or more recently doctoral training centres, are also prioritised for early career researchers, whilst rigorously enforcing standards of supervision, scientific quality and student achievement. We have introduced internal review and mentoring procedures to assist junior staff in PhD supervision. Testament to the success of these schemes, all eight NERC studentships received in 2013 were awarded to staff in their first year of appointment.

We are focussed on ensuring that researchers spend as much time as possible on actually doing research and target their grant-writing effort as efficiently as possible. We have introduced a

formal procedure for internal review of all RCUK grant applications at early stages of development. For example, in the last three rounds of NERC applications we have internally sifted out 40% of potential applications, through a system of hustings, carried out five months ahead of the deadline, where potential applicants pitch ideas to all other potential applicants (and any other researchers, including students who want to attend) followed by a review in which three people, including the Director of Research (DoR) read all applications. If a grant is rejected internally, two of the reviewers are assigned as mentors to advise on improving the proposal for a future application or to mentor the applicant in developing other aspects of their work. This has resulted in rising success rates of 30% for BBSRC and 36% for NERC in 2012-13.

Biosciences has two DoRs, one on each campus. Their core role is to maximise future research output. They are responsible for an annual non-pay research budget of £1.9m (2012/13) including grant overheads, which are strategically allocated to research groups and to support infrastructure. The DoRs meet individually with all members of staff at least twice a year to monitor progress and performance, discuss future plans and funding opportunities in an explicitly supportive atmosphere that emphasises the question: "what can we do to enhance your research?" DoRs meet at least once a month with Academic Leads, who are responsible for mentoring staff (weekly on our Cornwall campus, where many staff are junior), which allows for rapid responses to opportunities and problems.

We have an extensive program of internal and external seminars with at least three research seminars per week during term time. All PhD students and full-time researchers present their work to the whole School at least annually, in addition to group presentations and lab meetings. We have an annual research retreat: a two-day event attended by all academic staff from both campuses, dedicated to identifying and nurturing potential collaborations, which has facilitated award of £6.3m of cross-campus grants.

Twice yearly, all staff have the opportunity to bid for strategic research funds through a simple, transparent process from an annual allocation of £200K. Since 2011 these funds have supported ten projects of £5-£70K, varying from funding discrete research projects to developing new experimental techniques and buying equipment. Internal support for research is also facilitated through the Exeter Open Innovation Fund to support industrial links, which has funded 18 Biosciences projects (2008-13). The 'Business Voucher' scheme also enables businesses to buy academic time to carry out consultancy or develop collaborative research and has supported seven projects in Biosciences (2008-13). Cross-disciplinary funding aimed at pump-priming large-scale projects is also provided through the EPSRC-Bridging the Gaps Initiative, which is matched funded by the University and the Wellcome Trust Institute Strategic Support Fund.

Research Groups

Research groups have been formed to enhance capacity to address common research questions using complementary skills. All groups hold annual away days involving researchers from graduate students to professors, as well as contributing to cross-campus meetings and the annual retreat. Cross-group collaborations are very common, and research directions of individual researchers are not restricted.

The **Behaviour group** at our Cornwall Campus focuses on understanding social, sexual and competitive behaviour, studying how behaviour evolved and its mechanistic basis. Research is both empirical and theoretical, utilising recent molecular and biochemical techniques, experimental evolution studies in the lab and long-term field studies. A wide range of species are studied including insects, amphibians, birds and mammals, with field research projects across the globe. Current research includes studies of cooperation, predator-prey interactions, information use and transmission, ecology and biochemical basis of aging, parental care, selfish genes, life-history and developmental trade-offs, maternal effects, sexual selection and sexual conflict. *New staff (appointed in census period): Mike Cant, Tom Currie, Clarissa House, Shakti Lamba, Andy Russell, Martin Stevens, Alex Thornton, Andy Young.* Pre 2008 staff: Jon Blount, Sasha Dall, Nick Royle, Nina Wedell.

Key achievements since 2008 include:

£8m of awards including €1.5m ERC grant (Cant), ESRC future research leader (Lamba), Wolfson Merit (Wedell) and 2 BBSRC David Phillips fellowships (Thornton, Young).

50+ presentations at international conferences including Wedell's plenaries at the 2010 International Society for Behavioural Ecology conference, and 2011 SSE conference.

14 students awarded PhDs

325 publications including Martin Stevens' book on sensory ecology, and other highlights:

- Banded mongooses acquire adult foraging traditions as pups (***Curr Biol***, 2010, 20:1171-1175).
- Discovery of cues used by avian hosts to reject parasite eggs (***PNAS***, 2010,107:8672-8676).
- Demonstration that females rapidly evolve increased re-mating rates in the presence of a sex ratio distorting selfish gene (***Science*** 2008, 322:1241–1243).
- New insights into the evolutionary causes of menopause in humans (***PNAS*** 2008, 105:5332-5).
- Emergent, group intelligence can result from local interactions (***PNAS*** 2009, 106:22055-60).

The **Evolution Group** at our Cornwall Campus has strengths in the evolutionary ecology of host-pathogen interactions, sexual selection and studying selection in the wild. They use experimental evolution to investigate how changes in environment or mating patterns drive rapid evolutionary adaptation in microbes and insects and high throughput sequencing to dissect evolution at the level of the gene. Current projects include studies of aging, host-parasite coevolution, the genetic basis of mimicry, parental care, selfish genes, speciation and life-history and developmental trade-offs. *New staff (appointed in census period): Camille Bonneaud, Mike Boots, Angus Buckling, Florence Débarre, Celine Frere, Britt Koskella, Chris Lowe, Lena Wilfert, Alastair Wilson.* Pre 2008 staff: Richard ffrench-Constant, David Hosken, John Hunt, Allen Moore, Tom Tregenza.

Key achievements since 2008 include:

£7.4m of awards including a second NERC fellowship to Koskella and NERC awards to study genital evolution, the evolution of the G-matrix, and host-parasite coevolution.

More than 70 presentations at international conferences including Tregenza's 2011 plenary at the German Zoological Association and Koskella's Fisher Prize plenary at the 2010 SSE.

11 students awarded PhDs.

400+ publications including a* Nature *paper showing that Chromosomal rearrangements maintain a polymorphic supergene controlling butterfly mimicry and other highlights:

- Using a 'mark-recapture' approach, bacteria and their parasitic viruses shown to reciprocally evolve defence and counter defence over a matter of weeks in soil (***Science***, 2011, 332:106-9).
- Dozens of video cameras, individual tagging and DNA fingerprinting combined to measure natural and sexual selection in wild insects for the first time (***Science***, 2010, 328:1269-72).
- Reconciling observations of variation in both tolerance and resistance of hosts to parasites using dynamic game theoretical models (***PNAS***, 2008, 105:20786-91).
- Demonstration of the quantitative genetics of sex differences in parenting. (***PNAS***, 2008, 105:18430-5).

The **Ecology and Conservation group** at our Cornwall Campus focuses on pressing issues in animal ecology including: the impacts of renewable energy generation; interactions between wildlife, fisheries and agriculture (particularly in relation to TB in badgers and cattle); new techniques in monitoring movement in wild animals; over-harvesting; and the impacts of climate change. We combine field, laboratory, and modelling studies, carried out globally in ecosystems ranging from farmland to coral reefs. *New staff (appointed in census period): Lucy Hawkes, Robbie McDonald, Juliet Osborne, Amber Teacher, Steve Votier.* Pre 2008 staff: Stuart Bearhop, Annette Broderick, Brendan Godley, David Hodgson, Frank van Veen, Rob Wilson.

Key achievements since 2008 include:

£8.8m of funding awarded including €1.5m ERC consolidator grant to Bearhop.

31 presentations at international conferences including a plenary lecture by Godley at the 2011 Wenner-Gren Symposium, Kristineberg.

22 students awarded PhDs.

350 publications including 2 papers in Science on the ecological significance of tool use and spatial separation of foraging at seabird colonies, with other highlights including:

- Evidence that the threat to biodiversity from climate change has not been exaggerated: 10% of species face extinction this century if recent declines continue (***PNAS*** 2011, 108:12337-42).
- Evidence of the vital role of habitat conservation in enabling species to survive climate change (***Proc Roy Soc B,*** 2009, 276:1421-7).
- A new framework for studying transient dynamics in populations (***Ecol. Letts.*** 2011, 9:959-70).
- Badger social networks correlate with TB infection (***Curr. Biol.*** 2013 23: R915-6).

The **Microbes & Disease** group at our Streatham Campus focuses on understanding host-pathogen interactions at both a molecular and systems level including: novel approaches to antibiotic administration; molecular dissection of infection to identify possible therapeutic targets; development of novel diagnostic and therapeutic antibodies; integration of genomic technologies to control emergent infectious diseases; identification and exploitation of novel candidate antigens for vaccine development and integration of mathematical modelling in clinical decision making. Our goal is to deliver science that has a real impact on disease control. The group includes microbiologists, molecular biologists, mathematicians, plant scientists and immunologists. We now have one of the largest UK groupings in fungal biology with interests in fungal pathogenesis of both animals and plants. *New staff (appointed in census period): Rob Beardmore, Richard Chahwan, Micheal Deeks, Ivana Gudelj, Sarah Gurr, Ken Haynes, Tom Richards and Henry White*. Pre 2008 staff: Steve Bates, Alan Brown, Murray Grant, Stephen Michell, Steven Porter, Mark Ramsdale, David Studholme, Nick Talbot, Rick Titball, Chris Thornton and Bryony Williams.

Key achievements since 2008 include:

£21.4m awards including a €2.5m ERC advanced grant (Talbot), £4.5m Strategic LoLa (Titball), £2.0m BBSRC/Gates grant (Talbot), £1.2m BBSRC Resources grant (Haynes)

100+ presentations at international conferences, including the International Mycological Conference, 2010 in which two plenary speakers were from Exeter

28 students awarded PhDs.

345 publications including a Nature paper re-defining the fungal tree of life, with other highlights including:

- Successful re-wiring of bacterial signalling (***PLoS Biol*** 2010, 8:e1000306).
- Development of an improved diagnostic test for melioidosis via mapping of the human antibody response to *B. pseudomallei* infection. (***PNAS*** 2009, 106:13499-504).
- Demonstration of septin-mediated plant infection by a fungal pathogen (***Science*** 336:1590-5)
- Genome analysis of important plant-disease microbes; *Blumeria graminis*, *Hyaloperonospora arabidopsidis* and *Phytophthora infestans* (***Science*** 2010, 330:1549-51; ***Science*** 2010, 330:1540-3; ***Science*** 2010, 330:1543-6).
- Experimental verification, using synthetic ecology, of Levin's postulate that the form of a trade-off should determine the outcome of competition (***Ecol Letts*** 2013, 10:1267-76).

The **Cellular & Chemical Biology** group at Streatham seeks to explain how the properties of living cells emerge from the functions and interactions of their constituent molecules. Our research spans many scales from molecular structure through to cells and their interactions. Using a broad range of methods, including advanced live cell imaging, biochemistry, molecular genetics, x-ray crystallography, biophysics and mathematical modelling we investigate key cellular processes including the cell-cycle, cell and organelle motility, membrane function and trafficking, metabolism and energy conservation. The group has strong interactions with industry and the biotechnology sector, where research has applied a synthetic approach to Biofuel generation in bacteria and developed new strategies for molecular diagnostics. The group includes cell biologists, biochemists, chemists and plant scientists. *New staff (appointed in census period): Steven Penfield, Michael Schrader, Imogen Sparkes,* Pre 2008 staff: Steve Aves, Clive Butler, Helen Dawe, Mark van der Giezen, Nicholas Harmer, Tetsu Kudoh, Jenny Littlechild, John Love, Andrew Shaw, Gero Steinberg, James Wakefield, Mark Wood.

Key achievements since 2008 include:

£18.9m of funding awarded including £10m of grants from Shell (Love, Aves, Butler), BBSRC funding of £2.24m to Steinberg and £2.2m to Penfield.

90 presentations at international conferences including 4 plenaries at international mycology meetings by Gero Steinberg.

27 students awarded PhDs.

300 publications including papers in Current Biology and PNAS revealing a new mechanism through which warm temperatures accelerate plant growth and seed germination and other highlights including:

- Invention of a synthetic metabolic pathway for the production of retail-grade diesel by bacteria (***PNAS*** 2013, 110:7636-7641).
- Discovery of a novel process by which bacteria can make and secrete mineral nanoparticles (***PNAS*** 2011, 108:13480-13485).
- Revealing novel principles of motor cooperation in early endosome motility (***PNAS*** 2011, 108:3618-3623).
- Description of the mechanism by which organelles are loaded onto the retrograde transport machinery (***EMBO J*** 2011, 30:652-664).

c. People, including:

i. Staffing strategy and staff development

Exeter has invested significantly in Biosciences during the period (£56m in infrastructure alone since 2008). In the current assessment period we have made 33 new appointments. Our positive research environment is attested to by very high staff retention, with only three staff having moved to other institutions during the assessment period. Moreover, 28% of staff (20) are within five years of their first permanent appointment, and we expect their productivity to increase over the next 5 years. The total staffing cost as a percentage of turnover is 34%, well below the HEFCE good practice guide not to exceed 58%, providing evidence of further potential for sustainable growth. Biosciences in Cornwall has just been awarded the first Athena Swan Bronze award in the university and we are committed to achieving silver for the whole unit in the next two years. We have increased from having 4.0 fte female academic staff in 2008, to 16.9 fte in 2013, and our aim is to improve still further by a set of strategies formulated in our Athena Swan action plan, including proactively encouraging and supporting our best PDRAs to apply for independent fellowships and proleptic appointments, rather than simply assuming they will have the confidence to do this.

Developing the research of early career academic staff: We have a mentoring system for all junior staff. The principle aim of which is to advise junior academics on maximising research income and outputs, for instance by making strategic decisions on preliminary data generation to facilitate grant applications and that publications are submitted to appropriate journals. Mentors are assigned after discussions between mentees, DoRs and the appropriate Academic Lead of each of our research groupings. The research goals set by mentors for their mentees form part of individual Personal Development Plans that ensure that workloads for young academics do not put their research productivity at risk.

Valuing junior researchers: PDRA researchers are expected to write and be first author on work they carry out. All PDRAs choose an additional mentor from any member of staff who is not the direct supervisor of their project. Mentors meet with PDRAs at least every six months or any time upon request. We operate a merit award scheme that recognises outstanding contributions at all level with bonuses paid annually, which always recognizes PDRAs, and there are clear career progression routes for research staff. Our policies comply with, and exceed, the principles laid out in The Concordat to Support the Career Development of Researchers.

Personal Fellowships We encourage and support PDRAs and academic staff to apply for personal fellowships. There have been 22 personal fellowships in Biosciences since 2008, including seven Royal Society University Research Fellows, five NERC, three BBSRC David Philips, an EPSRC Leadership Fellowship plus fellowships funded by ESRC, Wellcome Trust and Leverhulme Trust. Of these fellows, we have subsequently recruited 20 as permanent academics in Biosciences, demonstrating a clear route to academic career advancement within the unit.

Support & Career Development: We have a rolling programme of development activities for researchers run by both Staff Learning & Development and more specific in-house courses such as specialised statistical, bioinformatics, and molecular biology skills. The University runs one day development centres several times annually which provide the opportunity for a small group of research staff to assess their competencies in areas such as team work, prioritisation and project

management which are sought after in both academia and industry. Researchers can request one to one meetings with members of the researcher development team at any time. By far the most important support for junior researchers is having a collegiate, mutually supportive research and management culture. We know this and are very focussed on ensuring it exists across Biosciences.

ii. Research students

Doctoral training is central to our research, and we are members of both BBSRC & NERC Doctoral Training Partnerships. We have worked hard to get the balance right between the essential freedom of academic supervisors and students to run their projects and ensuring that appropriate oversight and support is in place, within an intellectually stimulating postgraduate training environment. Following internal review, we have recently revised and simplified our processes for managing progression of doctoral students. At the start of a project the student completes a written agreement defining the roles and responsibilities of student and supervisor(s), and identifies individual training and support needs. Students are also assigned a mentor, who is not actively involved in the project. Meetings between supervisors and students are recorded through an electronic portal, *myPGR*, which allows monitoring of student progress and project supervision. Annually, students and supervisors independently assess supervision. This assessment, and the supervision record on *myPGR* is then reviewed by Directors of Postgraduate Research to ensure that appropriate training and support is being given and that progress is adequate.

Students initially register for an MPhil and at six months there is a one-day student conference where all first-year students present key questions and project aims. This talk and responses to questions from the floor are assessed and if progress is unsatisfactory an initial warning letter is issued. At 12 months the student completes a 5000 word report that outlines their progress and provides a critical evaluation of their work against the wider literature. The student has a *viva* with independent assessors. Transfer to a PhD programme is dependent on progress and performance at this *viva*. We have introduced a policy that if a student does not progress, the staff member has the opportunity to appoint a new student to a new PhD position. At 24 months, and with supervisor support, the student will set out a 'thesis work completion plan' with a clearly specified timeline.

Students are expected to engage fully with activities to develop their broader transferable skills. They give at least one oral presentation annually to the faculty through our internal seminar series and attend at least two external science meetings or conferences over the course of their PhD. They are also required to attend at least four training modules per year from an Effective Researcher Development Programme, which provides training in skills ranging from time management and study techniques, to management of careers.

More important than all these systems, but harder to document, we have developed an academic culture in which students feel able to ask any academic for assistance, where they ask many of the questions in research talks, and where social events are a mixture of researchers at all levels. In the national Postgraduate Research Experience Survey we are above the sector and Russell Group average for supervision (86% positive score) and overall PhD experience (83%). Several of our doctoral students have won prizes for their work, including Sam Weber awarded the 2010 Thomas Henry Huxley Award by the Zoological Society of London, for his PhD thesis and Iain Stott the prestigious Bob May Prize for best postgraduate author of a paper in 2010.

d. Income, infrastructure and facilities

Research Facilities at the Cornwall campus

All of our facilities in Cornwall have been built since 2004. They include a unique investment in facilities for ecological research:

Controlled Environment Rooms. With the 2012 addition of eight 12 m^2 CT rooms in the ESI, we now have 13 large programmable environment rooms with variable temperature and light regimes and shelving for insect rearing and plant growth applications, supported by a dedicated technician.
Greenhouses. Two large (69m^2 & 46m^2) fully programmable greenhouses with automated blinds and lighting systems and full racking for plant and insect rearing.
Insect radar. A harmonic radar for tracking individual insects and a vertical-looking radar for monitoring insect migration are being built at a cost of £200K to ensure Exeter is at the cutting edge of studying insect behaviour in response to environmental change.

Stable Isotope facility. In 2013 we commissioned our new stable isotope facility in the ESI, the Sercon facility has two isotope ratio mass spectrometers with elemental analysers allowing the dedicated technician to measure Carbon, Nitrogen, Sulphur, Oxygen and Hydrogen ratios.
High-Performance Liquid and Gas Chromatography. Complementing our Streatham facility we have a fully equipped laboratory for oxidative stress research, run by a core funded technician, including a Dionex high-performance liquid chromatograph (HPLC) with diode-array detector and flouresence detector configured for reverse-phase analysis of antioxidants; UV-visible light spectrophotometer for spectrophotometric analysis, e.g. protein carbonyls and antioxidant activity. Related equipment for preparation of samples includes refrigerated and vacuum centrifuges, sonicators, homogeniser and micronizer. The metabolomics lab is equipped with two autosampler Agilent 7890 gas chromatographs coupled with an Agilent 5975 mass spectrometer.
Aviary and Aquarium. A Home Office approved facility with dedicated support staff and up to 20 outdoor aviaries and 100 indoor cages for breeding and observational studies of small birds. Co-located with a 100 tank freshwater aquarium. The outdoor facilities provide aviaries ranging in area from 7-30 cubic metres. The indoor facility has full temperature and light control including simulated dusk and dawn cycles to provide state-of-the-art housing.
Unmanned aerial vehicle (UAV) facility. As part of our £2m equipment spend at the ESI we are currently in procurement for a facility to deploy UAVs as a tool in ecological monitoring.

Research Facilities at the Streatham campus
Biosciences at Streatham is now located primarily in the newly refurbished Geoffrey Pope Building which provides 4,817m^2 of lab space, much of which is configured as BSL2/GM2 laboratories. It also contains four controlled environment growth rooms (approx 20m^2 each) providing fully programmable day length, light intensity, temperature and humidity and four purpose-built positive pressure rooms for cell culture work. The building also houses the bio-imaging, sequencing, bioinformatics, X-ray crystallography, analytical biochemistry and mass spectrometry facilities; the 72m^2 BSL3 laboratory and associated mouse experimental room plus newly expanded aquarium. These facilities are complemented by an additional 550m^2 of lab space in the Sir Henry Wellcome Centre for Biocatalysis, which has just undergone a £136K refurbishment to accommodate an additional three groups led by individual academics. All facilities operate on a cost-recovery basis and are accessible to PIs at both campuses.

Aquarium. Our £9m aquarium facility complex, with 14 aquaria rooms, houses 600 experimental tanks and seven preparative and analytical labs. The unit is very flexible, allowing for marine and freshwater studies in both re-circulatory and flow-through conditions and also houses a Wolfson Foundation funded bio-imaging unit, used principally for studies on embryogenesis.
Bio-Imaging Centre. Holds two live cell imaging work stations based on Olympus IX81 motorized inverted microscopes equipped with Photometrics CoolSNAP HQ2 cameras one of which is equipped with a VisiTirf module and a VS-LMS4 Laser-Merge-System with dual wavelength laser based wide field fluorescence and TIRF microscopy. The second system is equipped with a CSU-X1 Spinning Disc and VS-LMS4 Laser-Merge-System with three lasers for spinning disc confocal microscopy. The facility also holds a Confocal laser-scanning microscope (Zeiss LSM 510 META) with Blue diode, argon and HeNe lasers. A recent £366K BBSRC ALERT 13 award (Steinberg, Gurr, Talbot) will provide a Leica TCS SP8 Laser Confocal microscope in December 2013.
BSL3 laboratory. Our 72m^2 BSL3 laboratory opened in 2008 and is approved by the Home Office and the US NIH for select agent work. We have two CL3 laboratories, one designed to allow work with mice.
Greenhouses. In 2010 we replaced our existing glasshouses at Streatham with a new purpose-built building. This has a footprint of 375m^2 divided into three compartments, with independent climate control, supplemental lighting and 57m^2 of bench space with automatic watering. One of the compartments is built to GM plant containment specifications. The three compartments provide conditions for growth of tropical and temperate crop plants for research.
High-throughput sequencing and bioinformatics. In 2008 Biosciences invested >£1.5m in an Illumina GA2 sequencer. In 2011 this was upgraded to an Illumina HiSeq 2000, and now 2500, and in 2013 augmented by an Illumina MiSeq. The facility employs two bioinformaticians and two wet-lab staff. This investment of over £3m has been supported by external funding of £500K from The Wellcome Trust and BBSRC. It has significantly increased links between Biosciences and the

Medical School, and resulted in significant collaboration with the new Wellcome Trust/Wolfson funded Diabetes Research Centre leading to discovery of new causative mutations of congenital hyperinsulism, limb malformations and pancreatic agenesis. A 396-core computer cluster in Streatham and a new £300K Beowulf cluster in Cornwall support this facility. This sequencing capability has acted as a catalyst for 25 separate external collaborations (e.g. sequencing the Ash dieback fungus *Chalara fraxinea* to inform countermeasures in collaboration with Fera) and has generated in excess of £4m in grant income. Most significantly, a £1.5m Wellcome Trust Institutional Strategic Support award has supported a Biomedical Informatics Hub that employs 10 ftes to provide informatics support for projects within the Wellcome Trust remit.

Mass spectrometry. Our Agilent 6520 QToF MS and Agilent 6510 triple quadrupole mass spectrometers are interfaced with high resolution LC via ESI or APCI ion sources and, for nanospray, with a microfluidic HPLC-Chip system. The MS facility is supported by a dedicated Senior Experimental Officer and carries out a wide range of targeted and non-targeted analyses of biomolecules. Proteomics research is supported by SpectrumMill and Progenesis LCMS software.

Synthetic Chemistry Facility. Equipped with a newly refurbished laboratory and a Bruker 300MHz NMR spectrometer and other essential analytical instrumentation, the facility allows us to synthesise and characterise organic compounds required for research across the University.

e. Collaboration or contribution to the discipline or research base

The majority of our work involves national and international collaborations which we facilitate through a variety of mechanisms: International Exeter run a visiting fellowship scheme allowing academics to fund travel, build relationships and collaborate on research projects with world leading researchers. Since 2008 Biosciences at Cornwall has been the largest partner in a major European Social Fund programme of £12m of investment in MSc and PhD provision. The programme has catalysed collaboration with industry, NGOs and the public sector through CASE-style PhD projects. We are active members of the *SETsquared* partnership, a collaboration between the Universities of Bath, Bristol, Exeter, Southampton and Surrey which enables enterprise activities and collectively supports the growth and success of new business opportunities through spin-outs, licensing and incubation (http://www.setsquared.co.uk).

We have developed numerous commercial, government and charitable bodies during the assessment period, including major funded projects with: BASF, Bayer, British Heart Foundation, Butterfly Conservation, CEFAS, Cornwall Wildlife Trust, DEFRA, Dstl, Fera, The Game and Wildlife Conservation Trust, Marine Life, MCS, Natural England, Syngenta, WCS, WWF, ZSL, and SMEs Antaria Ltd, CEMMNT Hub Ltd, Intrinsiq Materials Ltd, Oxonica Ltd, Umicore and Puricore. We have signed Memoranda of Understanding with Plymouth Marine Laboratory and AHFOS, we have a strategic partnership with the Dstl resulting in £4.7m of funding since 2008 (with an additional £2.5m associated with groups in other REF2014 UoAs).

Our staff have made numerous cross-university contributions, acting as external examiners for UG and MSc programmes at Birmingham, Bristol, Edinburgh, and Imperial College. Talbot is Chair of both the Sainsbury Laboratory Council and the Board of Directors, Rothamsted Research.

Journal Editing

Staff have held 104 positions as editors of international, peer reviewed journals, including *Ecology Letters*, *The Plant Cell, Molecular Biology of the Cell, Evolution* and *Proceedings of the Royal Society* and guest editorships of *PNAS and Phil Trans*. These include roles as Editor-in-Chief of *Journal of Evolutionary Biology* and *Ecology and Evolution* (Allen Moore), *Mammal Review* (McDonald) and *Endangered Species Research* (Godley). We have embraced open access publishing with 14 members of staff editing in the *PloS* and *BMC* open-access portfolio, and Tregenza on board of *Peerage of Science*. Staff sit on advisory boards of five journals and have edited six special edition journal issues since 2008. All staff referee for a wide range of journals and have received accolades for their contributions including Godley, Buckling and Stevens independently named as 'Top Referee' for *Proc. Roy. Soc. B.* in 2008, 2011, and 2012.

Grant committees

Exeter Biosciences staff have served on over 250 committees and panels since 2008. Gurr is a BBSRC Council member and has chaired numerous BBSRC grant panels during the period. A total of eight staff have served on BBSRC grant committees, including acting as Chair/Vice-Chairs (Richards, Talbot) and 14 on NERC panels, including Moore and Boots being members of the

NERC pool of chairs, with Moore chairing the NERC fellowship committee and Boots permanent chair of the Evolution panel. Nine staff members have been on ERC or MRC grant panels, 11 on Royal Society panels and three on EPSRC committees with Beardmore and Littlechild both serving on the Centres for Doctoral Training Panel. Staff have sat on committees for ten overseas grant awarding panels including the major funding agencies in Germany, Finland, Norway, Belgium and Canada. Other panels in the UK include the Nuffield Foundation and Wellcome Trust, with Haynes being a Founder Member of the Wellcome Trust College of Experts, Godley a ministerial appointee on Defra Darwin Initiative Panel and Boots appointed to the REF2014 UoA5 panel.

Contributions to Societies and NGOs

UK and international learned societies have benefited from the input of 33 of our staff to society committees. Additionally several of our staff have taken on major elected roles: Wedell is President-Elect of the *International Society for Behavioural Ecology*, spent five years as the treasurer of the *Association for the Study of Animal Behaviour*, has been the Non-North American Vice-President of the *Society for the Study of Evolution*, and is a trustee of the *Royal Entomological Society*; Gurr has served a full term as *President of the British Society for Plant Pathology*; Hodgson is Honorary Secretary of the *British Ecological Society*; Wakefield is Membership Secretary for the *British Society for Cell Biology*; Hosken edited the Genetics Society Newsletter; and McDonald has served as Vice President of the *International Federation of Mammalogists*. Nineteen of our staff are members of NGO steering committees, including Godley being a member of Council, Fauna and Flora International, a member of the IUCN-SSC Sustainable Use and Veterinary Specialist Groups and Scientific Advisor to Conservation International.

Invited talks by Exeter staff

The number of Invited talks at conferences and other academic institutions by our staff provide evidence of their influence within their research fields. Every member of our staff has given invited talks, with more than 550 external seminars since 2008. Talbot has given 14 invited plenary talks, including numerous distinguished lectures such as the Karling Award Lecture of the 2008 Mycological Society of America Conference; and plenaries at the 2009 International Congress of Molecular Plant Microbe Interactions; and the 2010 International Mycological Congress. Other major plenary lectures have been given by Steinberg, who among his 67 external talks, gave invited plenaries to the 2010 International Mycological Congress and the 2013 International Fungal Biology Conference. Wedell presented to thousands of attendees at the 2011 Evolution Conference USA and the 2010 International Behavioral Ecology Congress.

Conferences organised

We have organised more than 70 conference symposia and major workshops in 42 different countries since 2008. Examples include the 2009 Winter Conference of the Association for the Study of Animal Behaviour organised by **Dall**, and the 2011 Society for Experimental Biology three-day Glasgow symposium “Frontiers in Algal biology” organised by **Love**. We have run eight separate conferences and international workshops at our Cornwall and Exeter campuses including the British Mycological Society meetings in 2010 and 2011, and the 2013 European PhD Students in Evolutionary Biology meeting which our PhD students organised at the Cornwall campus, including an evening programme 'For the love of science' open to the public, featuring talks and Q & A sessions from members of staff.

Fellowships and Awards

Talbot was elected as a member of EMBO in 2013 and awarded the Whetzel-Westcott-Dimock Award of Cornell University in 2011. Richards received the Society for Experimental Biology President's Medal for Cell Biology the Berkeley Award of the British Mycology Society in 2012, an award which three years earlier was won by another member of our staff, Bates. Lowe received the 2013 International Society for Protistology William Trager award. In 2010, Love was Winner of the European Biophysics Award and Koskella received the Fisher Prize from the Society for the Study of Evolution. Godley received the Zoological Society of London’s Marsh Award for Marine and Freshwater Conservation in 2012 and in the same year Moore was made a fellow of the American Society for the Advancement of Science. Wedell and Buckling are holders of Royal Society Wolfson Merit Awards in recognition of their value to the UK research community.