

Institution: University of Reading
Unit of Assessment: 5 Biological Sciences
<p>1. Unit context and structure, research, and impact strategy</p> <p>The Ecology and Evolutionary Biology Research Division (EEB) is a vibrant community of researchers within the School of Biological Sciences (SBS). The multi-disciplinary investigations undertaken by 19 research staff (15.7FTE), 7 postdoctoral researchers and 65 doctoral students focus on understanding fundamental questions in biology. We do so by studying organisms and their environments, examining large-scale phenomena and complex trophic interactions, and applying the outcomes of our research to real world problems, in turn influencing the public, government and industry. We achieve this by building on our core research strengths and growing connections between the research groups within EEB and across the University and beyond.</p> <p>Within the University, EEB is one of two research Divisions in SBS, and one of nine Research Divisions in the University of Reading's Environment Research Theme. Environmental research is centre stage at the University of Reading. Two hundred academics, and hundreds of postdoctoral researchers and PhD students come together within our Environment Theme to investigate, understand, and address the challenges of environmental changes, both natural and those shaped by humans.</p> <p>The international reputation of EEB is founded on our ability to deliver excellent ecology and evolutionary biology science that addresses important questions about the history and future of the living world. Our staff work on diverse topics from those working on a target species, to species interactions, to those working at deep timescales. Excellence in quantitative research, both applied and method development, is central to the vast majority of EEB's research. EEB's reputation was recognised in February of 2019 when The University of Reading was ranked the number one UK university (59th in the world) for citations in environmental and ecological research based on InCites Essential Science Indicators rankings.</p> <p>Progress since REF 2014</p> <p>The University of Reading's Unit of Assessment 5 (UoA5) submission in 2014 comprised all staff within the School of Biological Sciences (Microbiology; Molecular and Cellular Medicine; Ecology; Evolution). Following the University's reorganisation of research management structures in 2015 (see Institutional Environment Statement), EEB was created to build on the strengths identified in ecology and evolution. These developments were supported by the strategic appointment of 5 new permanent members of academic staff since REF2014 (an increase of 4.8 FTE), to strengthen our ecological research portfolio and further integrate the ecology and evolutionary biology branches of the division. Our UoA5 submission for REF 2021 comprises only research staff from EEB, with the remainder of the School being submitted under UoA3.</p> <p>Our UOA 5 aims from REF 2014 were: 1) to continue to be recognised internationally as one of the leading university organisations for broad-based biological sciences in the UK as measured by our research excellence, research income, research publications in elite journals, and its impact, fostered by targeted investment in people and infrastructure; 2) to be amongst the top 10 UK institutions of choice for highly qualified UK, EU and international postgraduate student researchers, measured by our success in recruitment and their subsequent employability in career-track positions, underpinned by an outstanding training programme.</p> <p>These aims remained pertinent and, with them in mind, we set out two key strategic objectives for the new EEB division:</p> <p>1) Grow and broaden ecological research and its application, using approaches such as mechanistic process modelling, statistical ecology and high-performance computing to address</p>

challenges in areas such as climate change adaptation, design of habitat networks and agri-environment schemes, developing forensic sciences, usage of biopesticides, conservation biology, and urban ecology.

2) **Grow and broaden the application of research into evolution and grow our international reputation** in the development and novel application of phylogenetic methods. We planned to develop new statistical methods to incorporate fossils and geographic data into phylogenies, to detect natural selection on phenotypes, and to probe gene network evolution and adaptive landscapes. We also planned to better understand human and cultural evolution by applying phylogenetic methods to ethnobotanical, linguistic and ectoparasite data. We aimed to apply evolutionary methods to study systems of practical significance, exploiting our taxonomic expertise to influence forensics, and co-opting approaches from experimental evolution to inform cancer biology.

Achievement of these objectives is facilitated by:

- **Strong and supportive leadership** provided by the Research Division Lead (RDL) who is responsible for leading in the development and delivery of the division's strategy. The RDL is supported by the Research Dean for the Environment Theme, with whom the RDL meets frequently. The Research Dean facilitates interdisciplinary dialogue and collaborations across divisions and themes and supports engagement with external agendas.
- **Enhanced support for researchers** through increased research support and improved facilities (see section 3).
- **More dynamic and inclusive** research environment through greater involvement by all staff and students in the strategic planning and decision-making processes to achieve a sense of collective ownership.
- **Establishment of research groups** within the division, comprising EEB's staff, postdoctoral researchers and doctoral students, and thus creating **critical mass** to advance research in our priority areas.

These changes in structures, leadership, community and support have resulted in grant capture beyond the targets we set ourselves for the period, and an increase in the delivery of outputs. During this REF period we have been awarded research grants and contracts for a total value of £6.8M, representing an annual average of £62K/FTE. We have also contributed to 482 published original research articles.

Research Groups

EEB's research is carried out by the two broad interrelated groups, **Ecology** and **Evolutionary Biology**.

Ecology: Our ecologically focused 8.5 FTEs have strengths in molecular ecology, field ecology and modelling skills, including advanced quantitative methods such as mechanistic process modelling and statistical ecology. We apply these skills to address applied challenges in areas such as climate-change adaptation, design of habitat networks and agri-environment schemes, forensic sciences, biopesticide usage, conservation biology, and urban ecology.

We have expanded our work on the development of **innovative applications of ecological research**. For example, **González-Suárez's** recent work has examined the influence of road networks on biodiversity, and pinpointed traits associated with vehicle and traffic avoidance. We have also had successes in the identification of species' life-history, ecological and behavioural traits that can be used as predictors of extinction risk (**González-Suárez**) and invasion success (**González-Suárez and Venditti**). **Oliver's** research, which takes novel approaches to conservation using butterflies and birds as indicator species, has revealed how the range, arrangement, connectivity and size of habitats within modern landscapes are vital for biodiversity. His work shows how restoring the 'functional connectivity' of habitats improves the resilience of butterflies and other populations to threats such as extreme weather events. He has

developed new methods to quantify which elements of landscapes, such as ‘corridors’ or stepping-stones of meadows, woodland, flower-rich field margins or road verges, successfully connect species populations, thus allowing a ‘species-eye’ view of habitat connectivity. This group is also involved in pioneering research that uses Next Generation Sequencing and High-Performance Computing (HPC) to investigate microbial ecology and biodiversity. Such innovative approaches have led to important developments in the genomic surveillance and nutrient influences of harmful bacteria (*Klebsiella* and *Escherichia*) in high-use environments such as hospital sinks (**Gweon**). We also concentrate research in host-symbiont interactions and nutrient dynamics in forest ecosystems (**Pickles**) and seek to integrate soil ecology and ecological theory into land management practices (**Pickles** and **Sibly**). **Sibly** is a pioneer in the development and application of individual-based models to predict the impact of habitat conversion and climate change on African elephants, as well as a variety of other animals.

Research in ecology has significantly influenced science-policy. **Holloway** and **Murn** have shown that poisoning, especially by poachers, poses the greatest threat to African vultures. African vultures are a conservation priority owing to population declines exceeding 80% and their ecological importance as obligate scavengers. They used local and continental-scale assessments to help quantify and highlight these declines, outline the problem and drive changes to the conservation status of vultures at the international scale. Subsequently they have quantified the high mortality risk vultures face from poisoning that occurs as part of criminal activities such as elephant poaching, and then showed the benefits of reduced mortality from poison response actions. These actions have been incorporated into international policy (Convention on Migratory Species), contributed to national-level action plans (South African National Parks, Kenya Wildlife Service) and also deployed in the field to reach over 2,000 personnel with our in-country partners, the Endangered Wildlife Trust (South Africa) (see Impact Case study for more detail). **Oliver**’s research continues to generate compelling ecological evidence that informs and influences environmental policymaking nationally and internationally. For example, his work is cited by Natural England as “vital to help us target conservation at the species level” and featuring in their Climate Change Adaptation Manual, which has informed and prioritised action on the ground. His analysis of biological records data to understand changes in over 4,000 species and potential effects on ecosystem functioning is currently being used by the UK Natural Capital Committee, and his analysis of moth population trends contributed 18% of data in the influential UK State of Nature report 2016, which influenced the Defra 25 Year Environment Plan. Academic reputation in this area is evidenced by an invited perspectives paper on biodiversity loss in the journal *Science*, and a seminal paper on biodiversity and the resilience of ecosystem functioning (published in *Trends in Ecology and Evolution* in 2015 and cited 541 times since then), along with his role in leading NERC and iDiv Centre working groups on biodiversity loss and its impacts. Oliver is currently on part-time secondment with Defra where he is leading a team of 5 other seconded academics as ‘design authority’ for their Defra systems research programme influencing policy design, such as for the UK net zero 2050 target. This position is key for introducing new systems methodologies to change Defra’s ways of working and developing new links between policy and academia to address urgent evidence needs in a timely way.

Informing the private sector and public engagement. **Prescott** is Director of the University of Reading’s Vertebrate Pests Unit (VPU), which leads in the field of rodenticide research, development and regulatory assessment, with particular focus on a major global issue: anticoagulant resistance. Working with a number of industrial partners and local authorities, the VPU has received in excess of £1.04M since 2014 and employs an academic and two technical FTEs. The development of anticoagulant rodenticides revolutionised rodent control in the 1950s, and in combination with recent regulatory restrictions, they are now the most common control method for these pests; however, rodent physiological resistance to anticoagulant rodenticides is now widespread. Rodents are major global pests that consume our foods, damage structures through gnawing, cause contamination, transmit many diseases, and impact on wildlife globally, creating concerns for conservation. Since 2005, VPU has developed and applied new methodologies to identify the genetic basis for anticoagulant resistance in Norway rats and house mice, to map resistance across the UK, Europe and elsewhere, and to quantify resistance

at the population level for each of the resistance mutations. These data are submitted directly to the Health & Safety Executive in support of the UK Rodenticide Stewardship Regime, resulting in new regulated guidance for the control of resistance by pest controllers, farmers and gamekeepers. This has enabled tailored and efficient control of rodent populations across the UK, thus prolonging the commercial lives of these important products (see Impact Case Study for details). Our Staff also seek to guide research students to excellence in public engagement, for instance Chanida Fung under the supervision of **Gonzalez** and **Oliver** won the British Ecological Society's public engagement award. In addition, **Culham** led a team including PhD students to win a Chelsea Flower Show gold award with an exhibit highlighting invasive species.

Evolutionary Biology: Comprising 7.2 FTEs, this group's research seeks to understand and investigate evolutionary processes operating at many different spatial and temporal scales via the development of innovative statistical methods to incorporate fossils and geographic data into phylogenies, to detect natural selection on phenotypes, and to probe gene network evolution and adaptive landscapes. Methods are applied to understand human and cultural evolution using ethnobotanical, linguistic and ectoparasite data. Furthermore, we apply evolutionary methods to study systems of practical significance, for example, exploiting our taxonomic expertise to influence forensics, and co-opting approaches from experimental evolution to inform cancer biology.

Pagel, Meade and **Venditti** continue to introduce **novel statistical modelling approaches that are revolutionising phylogenetics and incorporating them in to two widely used programs** which are often considered the *de facto* standard for macro-evolutionary studies. The two freely available and open-access and open-source programs [BayesTraits](#) and [BayesPhylogenies](#) are downloaded worldwide on average 3000 times each month and have been integral to 10 papers published in *Nature*, *Science* or *PNAS* by the group during this REF period. **Pagel** and **Meade** have recently won two further grants to progress methodologies: one to further develop new methods to infer and date phylogenetic trees (BBSRC, £368K), and the other (along with **Venditti**) to introduce novel comparative phylogenetic methods for phenotypic evolution (Leverhulme Trust, £180K). In addition, this year **Venditti** was awarded a five-year Leverhulme Trust Research Leadership Award (£1M) to develop and apply macro-evolutionary techniques to understand hominin morphological evolution and biogeography.

These novel phylogenetic methods have been also used by the group to address long-standing questions in evolutionary biology. **Pagel, Meade, Baker** and **Venditti** have demonstrated adaptive trends in several contexts, from mammalian body size increasing to a reduction of testes size in monandrous birds. We have also been able to show how adaptations inferred from phylogeny and species characteristics, often many millions of years in the past, can be explained by ecological environmental changes (**Venditti** and **Baker**). **Venditti** has also implemented phylogenetic comparative techniques to better understand the 'special' nature of the human brain and in recent years specialised in applying such methods to the fossil record. For example, he showed how dinosaurs were in decline tens of millions of years prior to their final extinction.

Our strength in phylogenetic studies goes further; we have used them to understand human and cultural evolution via their application to ethnobotanical and linguistic data. **Hawkins**, following the success from the last REF period, is now influencing the field of biodiversity-led research into medicinal plants and their uses. This has led to several influential papers including a recent perspectives article describing how comparative phylogenetic methods can be applied to revolutionise understanding of the cultural evolution of medicinal plant use (*Nature Plants*). Likewise, **Pagel** and **Meade**, continue to make significant contributions to the understanding of language evolution by combining data about languages and cultures to family trees of language. Within the current assessment period they have identified: regular sound changes in linguistics as events of concerted evolution, that number words are stable for thousands of years; and that dominant words are maintained by positive frequency-dependent selection.

Our endeavours in applying evolution methods to real world situations has also been fruitful. Our success in exploiting our taxonomic expertise to influence forensics highlights this. Perotti has changed the landscape of forensic acarology, which uses mites in forensic investigations, crime case reports and evolutionary research. **Johnson's** experimental evolution approach has demonstrated rapid repeatable rewiring of regulatory networks: a nitrogen regulatory gene evolves a new function, restoring flagella to immotile bacteria (*Science*). She has continued to demonstrate her flexibility in applying evolutionary thinking in understudied systems which has led to her securing funding (£311K) to investigate the phenotypic and genetic evolution of cancer cells informed by classic population biology theory; this has already proved fruitful (e.g., *BMC Evolutionary Biology*).

Approach to impact

We take several measures to ensure an effective impact culture across EEB:

- i. the appointment of an academic Impact Lead who promotes and encourages impact culture and development across our division;
- ii. facilitating and encouraging staff to consider impact early in the development of their research questions, with emphasis on co-designing projects with end users and working closely with stakeholders;
- iii. providing staff with resources, time, tools and training needed to identify, exploit and develop impact opportunities; and
- iv. recognising and rewarding impact successes.

Our impact work has been strengthened through several key initiatives, including support for impact development through the University's Building Outstanding Impact Support Programme, which brought £25k funding into projects and dedicated impact support (BOISP) (see IES). Impact is also incorporated into performance, reward, and recognition processes, such as probation, performance development-review, workload allocation and promotion processes; and is an important consideration in recruitment of new academic staff. These strategies have succeeded in embedding impact in our UoA as demonstrated in the examples in Section 4 of this statement.

EEB members participate in the UoR [Open in Practice](#) workshops and are thus well informed of the University's Open Research strategy (IES Section 2.2). Open access publication is strongly promoted within our Division by the RDL (with Green Open Access the minimum requirement). University and School-level Gold Open Access funding sources encourage such publication. Where appropriate, staff are encouraged to use preprint servers (e.g., bioRxiv) as well as open journal submission systems and open peer review (e.g., Frontiers journals). We generate open software for evolutionary studies (e.g. [BayesTraits](#) and [BayesPhylogenies](#)) and where appropriate deposit primary data at repositories (e.g. [DRYAD](#))

Our School-level Ethics committees review all relevant research projects, with those requiring higher level scrutiny reviewed by University Ethics. We apply the highest standards of integrity in our research in line with University policies (IES section 2.2).

Future strategic aims and goals for research and impact: our vision for the next 5 years

The EEB research division conducts high-impact research in areas of strong relevance to the global environmental challenges faced by society. In an era of rapid environmental change, understanding the natural world has never been more important. Our future objectives aim at EEB continuing to be at the forefront of developments in our research areas.

In the **ecology research group**, we will continue to answer fundamental questions in biology by studying organisms spanning plants, animals, fungi, and micro-organisms, including their interactions with the environment at a range of spatial and temporal scales, plus complex trophic interactions. We will apply the outcomes of our research to real world problems, in turn influencing the public, government and industry. We have strengths in molecular ecology, taxonomy (especially invertebrates and plants), field ecology, and modelling skills, including advanced quantitative methods such as mechanistic process modelling and statistical ecology.

We will continue to apply these skills to address applied challenges in areas such as climate change adaptation, urban ecology, macroecology, conservation biology, forensic sciences and landscape ecology. Over the next five years our aim is to develop more interdisciplinary collaborations across the University and beyond. Key parts of our research vision are elements of outreach and impact, developing new ways to communicate our science and working to actively reform the science-policy interface.

In **evolutionary biology**, we will continue to investigate evolutionary processes operating at many different spatial and temporal scales, for example developing innovative statistical methods to incorporate fossils and geographic data into phylogenies, to detect natural selection on phenotypes, and understand molecular evolution. We will study major evolutionary transitions that influence both historical and current biodiversity patterns. A significant challenge to understanding the effect of past climate change on species diversity is a lack of robustly time-calibrated phylogenies – we will develop new methods that address deficiencies of current, widely used methods. We will make these tools available to the academic community, building on our previous widely used phylogenetic software such as *BayesTraits* and *BayesPhylogenies*. We will apply phylogenetic methods to understand human and cultural evolution using ethnobotanical and ectoparasite data, including commensal mite fauna of ancient peoples, and modern great apes and humans. Furthermore, we will apply evolutionary methods to study systems of practical significance, for example, evolutionary models applied to human cancers and the evolution of human traditional knowledge, culture and language.

2. People

Staffing strategy

EEB REF eligible staff comprises 19 staff, of which 6 are Professors, 5 are Associate Professors, 5 are Lecturers and 3 are research fellows. Four of our staff are Early Career Researchers (ECR). During the REF period we have had four independent fellows: **Gripenberg** (URF); **Johnston** (NERC); **Melero** (MSCA); **Baker** (Leverhulme Trust).

Our staffing strategy in support of our objectives is aimed to: (1) Build on existing strengths to enhance EEB's reputation in areas where we enjoy international recognition (quantitative ecology and evolutionary biology). (2) Recruit into areas of national and international priorities that complement existing programmes (conservation, biodiversity, landscape ecology, applied ecology). We have delivered our strategy through the following actions:

(1) Targeted recruitment. Selecting, recruiting and retaining researchers with the greatest track record and/or the highest potential to achieve excellence in research through strategic appointments. Since REF 2014, EEB has recruited 5 additional permanent academic staff (Oliver; Pickles, Gonzalez-Suarez, Gweon, Gripenberg) in areas of expertise (described above) to foster long term growth and multidisciplinary research. Subsequent to their appointments, Oliver has been promoted to Professor, and Gonzalez-Suarez and Gripenberg promoted to Associate Professor, highlighting our commitment to new and early career staff.

(2) Early Career Staff. All ECR staff are supported by two senior mentors in EEB. Regular meetings help identify training and funding needs to enable development. These are focussed on supporting the consolidation of research independence and mentoring in promotion applications. Teaching & Research ECRs participate in the HEA-accredited Postgraduate Certificate in Academic Practice, which includes training in research team supervision, postgraduate supervision, grant preparation and grant management (passing of probationary periods and promotion are conditional on the completion of the Certificate) - all academic ECRs appointed in the assessment period have completed this training. We develop and support research staff using the framework provided by the local and national Research Concordat, and UoR has the HR Excellence in Research Badge to demonstrate European Commission recognition for its plans to implement the Concordat. For postgraduate researchers, the Reading

Researcher Development Programme (RRDP) delivered by the Graduate School is a major element of support through training (see Institutional Statement for details).

(3) Annual research planning. EEB participates in the University's staff Personal Development Review (PDR) process, which is used to set objectives for the coming year. Each staff member's PDR submission includes a Personal Research Plan which is used to develop research ambitions over the next five years. Workload data are collected as part of the PDR process, and enable yearly staff workload reviews. These allow the Head of Department to identify teaching and administration commitments and balance these against strengths and successes in research and plans for future research activities.

(4) Financial support for research. Start-up funds (typically £10,000) are allocated to new staff enabling them to consolidate timely establishment of an independent research programme. A total of 4 fully funded PhD studentships were allocated to staff employed since REF 2014. Any staff consultancy income is allocated to staff development accounts, which are available for staff to spend freely to enhance research success. Pump priming research funds are available via internal application at both at Division (on average £20K is available each year) and at the University level (see IES, section 4.2).

(5) Research time and researcher mobility. The School takes a proactive approach to ensuring staff have sufficient time for research. This is supported by carefully managed workloads informed by research priorities. In addition, new staff and ECRs have no teaching in their first year, and a reduced load in their second and third years, to enable them to develop their research at Reading. The importance of secondments and associate positions at other organisations is widely supported and facilitated. For example, **Oliver** is currently on secondment under the Defra systems research programme (see section 1), **Pagel** is an External Professor at the Santa Fe Institute; and **Hawkins** is an Associate at Royal Botanic Gardens, Kew.

(6) Promoting diversity, inclusion and equality. The University is committed to promoting equality and has appointed a Dean for Diversity and Inclusion who supports Schools in local initiatives. SBS has a Diversity, Inclusion and Wellbeing (DIW) committee that has oversight of these matters, ensures that policies and practices are appropriate and engages with the certification schemes that recognise good practice. The committee undertakes regular surveys in addition to those at the University level to identify the impact of activities as well as specific issues that affect our research activities. Work is divided into thematic priorities focused on race, ethnicity, culture (theme 1), gender, career progression (theme 2), disability, health, carers (theme 3), sexuality and LGBTQ+ (theme 4). The school was awarded an Athena Swan Silver award in May 2020. DIW activities are a standing agenda item for our monthly EEB meetings, attended by academic staff, PDRAs and Fellows, supporting promotion and dissemination of initiatives and training. EEB staff are active in a number of these initiatives, for example organising the SoapBox science event for Reading, which raises the profile of science-careers for females.

In line with the University's REF2021 Code of Practice, all key staff involved in preparation of our submission completed the REF-specific University D&I training module as well as unconscious and implicit bias training. The UoA output portfolio has been selected entirely on the basis of quality, as determined by subject relevance, and a self and peer review assessment system based on the principles of the institutional Research Outputs Support System (ROSS). We considered the outcomes of the institutional interim Equality Impact Assessment (2020) and the bias analysis on our final pool (2021), which found no statistically significant differences for protected characteristics in our selection.

(7) Postdoctoral Research Assistants (PDRA) and Postdoctoral Fellows. To ensure that all members of our postdoctoral community can develop and contribute as young researchers, a School Director of Postdoctoral Researchers (DoPDRA) and PDRA committee were introduced during the current REF period. Collectively, the DoPDRA and the committee raise awareness of

career development opportunities. These include outreach initiatives, and specific funding and career accelerator schemes, such as the Young Entrepreneurs Scheme. We keep to a minimum the distinction between academic and PDRA, Independent Research Fellows and Research Assistant staff, to encourage all to take advantage of the University's extensive staff development programmes. This includes the opportunity to gain teaching qualifications through the University Academic Practice Programme (enabling the status of Associate Fellow of The Higher Education Academy) and to gain additional project management and supervisory experience by applying and managing projects through the Undergraduate Research Opportunities Programme (UROP). To raise the professional visibility of our early career researchers, all PDRAs are invited to have their own research web profiles and invited to give cross-division departmental seminars. The success of our new focus on the postdoctoral community is highlighted by Shirley Keeton's (an SBS PDRA) Royal Society funded initiative, '[Bring in the Bigger Brains](#)', for early career researchers to develop and implement research ideas.

(8) Research students. The recruitment, training and personal development of PGR students has been a longstanding priority for EEB. We have an annual average of 62 PhD students being trained by EEB staff. PGR come from across the globe (14 nationalities in our 2019/20 cohort) supported by a diverse funding stream that includes UKRI, industry, charities and foreign governments as well as university investment. We are involved in two doctoral training programmes. EEB is a major partner, along with Imperial College, of the **NERC Centre for Doctoral Training in Quantitative and Modelling Skills in Ecology and Evolution (QMEE)** which is focused on training a cohort of PhD students to solve real-world ecological and evolutionary problems by connecting theory, data, and practice. QMEE has registered 20 PhD students which are based in EEB. EEB is also an integral part of the **NERC SCENARIO (Science of the Environment: Natural and Anthropogenic pRocesses, Impacts and Opportunities) Doctoral Training Partnership**, which is now in its second 5-year term. SCENARIO has registered 11 PhD students which are based in EEB.

In addition to students from doctoral training programmes, a large proportion of EEB students come via other routes. In these cases, all projects submitted are scrutinised by the Research Division Lead and the SBS Director of Postgraduate Studies. All new students are allocated two principal supervisors and a Supervisory Committee of up to three academic members. Each research student's progress is reported to the University of Reading Graduate School at three points (6 months, 16 months, and 32 months). Progress is monitored by assessing written reports, oral presentations, through meetings with their supervisory committee and using student and supervisor evaluation forms. The support provided to our PhD students has resulted in 87% of students obtaining their degree with minor or no corrections following the first submission, and 10% passed after major corrections following first submission.

Since REF 2014, we have made significant improvements to PGR support services offered by EEB and SBS which are designed to complement those offered by the University. In addition to the introduction of a mandatory second supervisor, we have joint research lunches with students and staff (including PDRAs) where research ideas at early stages are presented and discussed. We have an annual SBS postgraduate symposium, where all EEB PhD candidates present a poster or full presentation. Our students have focused research-specific activities that are delivered through the research groups (for example, topic-focused seminar series and journal clubs). All training needs required for a particular research project are organised by a dedicated team within EEB who arrange workshops/courses. We also make opportunities associated with the CDT/DTP students open to non-CDT/DTP students. For instance, currently one of our Brazilian CAPES scholarship students has joined the QMEE cohort for training, also joining a Tiger Team project with external stakeholders. EEB students are particularly engaged in science outreach, for example winning the University three-minute thesis competition, coordinating the Reading Pint of Science event, and winning the British Ecological Society student outreach prize and a gold-award stand at The Chelsea Flower Show.

3. Income, infrastructure and facilities

Income

In the REF period EEB's external grant awards totalled £6.8M, with our annual average being £976K (£62K/FTE). Eighty percent of current research active academics have been PI/Co-I on externally funded research grants. We have increased our efforts to gain research funding from Research Councils and other UK bodies, with successes with BBSRC, NERC, Defra, the Royal Society and the Leverhulme Trust (see Section 1 for notable examples). We have expanded our interactions with UK charities. In addition, we have strengthened partnerships with global industries, including AstraZeneca and Syngenta (see Section 4). The breath of our funders is illustrated in the chart below:

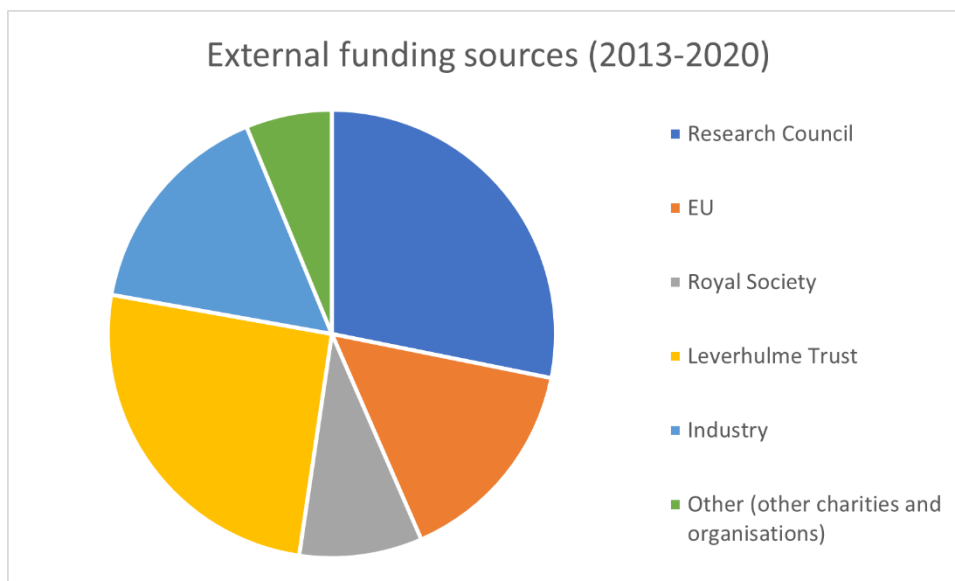


Figure 1: External funding sources 2013-2020

We have supported researchers in developing grant applications through division and institutional funding. Funds are awarded through competitive processes, with schemes open to all staff as well as schemes specifically targeting ECRs. For instance, the University runs an Open Call funded through the Research Endowment Trust Fund. Applications are assessed by the University Committee for Research & Innovation according to research excellence criteria, facilitating 'high-risk' research and supporting innovation via pilot projects. EEB has received funding these schemes, such as £22K awarded to **Page1** to support a pilot study to build the foundations of a new method to study historical phenotypic evolution on phylogenetic trees, which led to a successful Leverhulme Standard Grant Application (RPG-2019-170; 'The fabric of macroevolution') worth £180K.

Investment in infrastructure

The University has significantly invested in EEB in line with our strategic aims. The most significant improvement to EEB and SBS infrastructure has been the construction of the new Health and Life Science Building (HLS) at a cost of £55M (see IES, section 4.3). This new building will physically bring together all members of EEB, currently located in different buildings. HLS will be a centre of excellence in providing undergraduate and post-graduate teaching and research in areas of biological- and medical/health-related sciences for SBS.

In addition to physical infrastructure, the University has invested heavily in the provision of professional support for research and impact as detailed in the Institutional Environment Statement. For EEB, this has meant:

- enhanced support from the Research Development team, who work alongside researchers to develop applications, providing project management support for large and complex bids and facilitating workshops to explore ideas.
- support from the Impact Team established during this REF period, through a dedicated Impact Manager working with EEB's leadership to embed impact, whilst providing tailored support for impact projects, including our REF impact case studies
- enhanced support from the University's Knowledge Transfer Centre, with a member of staff co-located in the unit, providing an avenue to external business collaboration.

Facilities investment

To ensure that our research remains at the cutting edge, but also has the capability for the incorporation or development of new and emerging opportunities, we are upgrading our dedicated HPC facility, with a first phase completed in 2019 (£50K, Research England Strategic Priorities Fund) and a second phase being completed in 2021 (£225K, School and UKRI World-Class Laboratory funds). EEB led the charge for developing a UoR bioinformatics capability, funded through School and central funds. This initiative included funding for a specialist bioinformatics technician complemented by an academic position (**Gweon**) to lead the coordination and development of bioinformatics research in EEB. The facility has proven critical to maintaining and progressing the Division's international reputation in quantitative research.

We are supported by the University's Technical Support team, with 11 technicians working across SBS. The team is responsible for maintenance of the facilities and training in the use of equipment.

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

EEB has a prominent international profile across its main research areas and contribute to the shaping of national and international research landscape. EEB staff have made significant contributions to shaping local, national and international ecological and evolutionary research since 2014. Our collaborative efforts are reflected in our publications patterns: 61.8% of our publications result from international collaboration, with 22.6% from national collaborations. Just over 5% of our papers are derived from collaborations with industrial partner. Our UoA's contributions to society extend beyond our Impact Cases to influence diverse communities and the wider public.

Collaborations, Networks and Partnerships: contributing research on a global stage

We seek to facilitate local, national and international networks through a range of activities including:

CDT and DTPs. Our involvement in CDTs is a key means to facilitating productive national and international networks that are setting the future agenda. For instance, through the NERC QMEE CDT we collaborate with the four other hosting organisations (Imperial College, London; Centre for Ecology and Hydrology; Centre for Environment, Fisheries and Aquaculture Science CEFAS; and the Zoological Society of London), co-leading a consortium with complementary expertise in quantitative ecology and evolution, working in partnership with government, industry and charities. In addition to their individual projects, QMEE students form so called 'Tiger Teams' that work together with stakeholders in industry, government and charities to solve a specific problem. Partners have included [UN World Conservation and Monitoring Centre](#); [CABI](#); [Forest Research](#); [CEFAS](#); Defra and [Froglife](#).

International training networks. We played a significant role in the MedPlant Marie Skłodowska-Curie Initial Training Network, (Phylogenetic Exploration of Medical Plant Diversity). The interdisciplinary research project to explore the evolution and sustainable use of medicinal plant diversity consisted of 9 network partners from 9 European countries and 16 specialist associated partners globally. The network funded 13 Early-Stage Researchers (ESRs) and 2 postdoctoral projects; three of the ESRs were based in EEB and supervised by **Hawkins**.

International working groups. We encourage and support EEB staff to participate in international working groups. For example, **Oliver** led an interdisciplinary working group to identify mechanisms that ‘lock-in’ undesirable resilience in food systems to states which drive biodiversity declines, held at the German Centre for Integrative Biodiversity Research (iDiv). This working group brought together researchers from across Europe and from very different disciplines, resulting in an open access, interdisciplinary paper ‘Towards a bridging concept for undesirable resilience in social-ecological systems’ in the journal *Global Sustainability*. Oliver was invited to present this work at the 2019 US-UK Scientific Forum on Sustainable Agriculture, Washington DC, organised jointly by the National Academy of Sciences and Royal Society.

In other examples, **Meade** formed an integral part of a group brought together by the Netherlands Institute for Advanced Stud-Lorentz Center Program, which promotes cutting-edge interdisciplinary research that brings together perspectives from the humanities and/or social sciences with the natural and/or technological sciences. And the Capturing Phylogenetic Algorithms for Linguistics group brought together researchers from across Europe to innovate the statistical classification of human languages based on methods devised for building phylogenetic trees of species. The group went on to influence the field by hosting two international conferences (Capturing Phylogenetic Algorithms for Linguistics, Leiden 2015; and Phylogenetic Methods in Historical Linguistics, Tübingen 2017).

Impact of our collaborations, networks and partnerships: contributing impact on a global stage

Colleagues are encouraged to work with external partners and stakeholders/end users in the design and undertaking of their research. Interactions are supported by our KTP and Impact Team as detailed in section 3. Two major examples of our UoA’s impact on a national and global stage are detailed in our Impact Case Studies. Since 2014, we have developed interactions with stakeholders such as the [AHDB](#); [The Harding Foundation](#); and the [Commonwealth Commission](#). Our research has made it possible for us to strengthen our links with CEFAS, Syngenta, the European Food Safety Authority and the European Environment Agency amongst others. In addition to some examples covered in section 1.

Sibly has pioneered work on individual-based models, (IBMs) which are used to design conservation strategies. Sibly is currently working with CEFAS, and colleagues in Reading’s School of Agriculture, Policy and Development, to develop a technique which links the modelling with satellite information to enable the identification of fish locations. He has also used historical elephant movement in Africa to determine how populations and numbers will change under different future climate scenarios. A further application is for butterfly conservation in field margins (research partly funded by Syngenta). Several aspects of Sibly’s research on IBMs have been incorporated in the European Food Safety Authority (EFSA) [Scientific Opinion on good modelling practice](#).

Oliver’s research on biodiversity and ecosystem services appears in POSTbriefs (e.g., Urban Green Infrastructure and Ecosystem Services & Understanding insect decline: data and drivers), the UK Government’s Climate Change Risk Assessment 2017; Natural England Chief Scientists Report 2016-17; Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report and IPCC Special Report on 1.5°C warming and the 2018 IPBES (Global Assessment). His research is currently informing analyses by the UK Natural Capital Committee on consequences of biodiversity loss for ecosystem functioning. **Oliver** also sits on the European Environment Agency (EEA) Scientific Committee (2016-present) involving four meetings per year in Copenhagen to provide advice to inform research spending by the European Environment Agency to inform European Commission policy (€55.5M annual budget).

Hawkins’ work with the Medicines and Healthcare products Regulatory Agency (MHRA) has resulted in the publication in the British Pharmacopoeia of guidelines for the DNA barcoding of medicinal plant products. These DNA tools can now be used by industry for the authentication of traded plant products.

Perotti's research advances the use of mites and lice in modern forensics. Her research underpins the growing recognition and adoption of Forensic Acarology as a sub-discipline of modern forensic entomology. Protocols developed by Perotti, and the subsequent training she has designed and delivered, have provided law enforcement agencies around the world with new tools for the analysis of arthropod-based trace evidence at crime scenes. Perotti has been involved in the analysis of evidence in 30 criminal investigations, and acting as an expert witness for Coroners, Prosecutors and Judges in six cases.

Leadership and contribution to the discipline and research base

Members of EEB hold a range of invited Fellowships that reflect their leadership and broader contribution in the ecological and evolutionary communities. For example, **Pagel** has been a Fellow of the Royal Society since 2011. **Meade** is a Fellow of the Netherlands Institute for Advanced Study. **Gweon** is a NERC Centre for Ecology and Hydrology Fellow. Our academics also hold visiting titles in a variety of other international institutions. **Pickles** is an Affiliate Professor at the University of British Columbia; **Pagel** is an External Professor at the Santa Fe Institute; **Hawkins** is an Associate at the Royal Botanic Gardens, Kew; and **Oliver** is senior academic fellow at Defra.

Within learned societies, EEB staff have been appointed to decision-making roles. For example, **Culham** is a Member of the Science Advisory Panel for the Royal Horticultural Society. During this period of assessment **Pagel** has been a member of several Royal Society panels, including the Grants Committee, Fellowship Committee and is Chair of University Research Fellowships panel and the Small Grants Panel.

Our staff act as editors for numerous journals. For instance, **Gripenberg** is Associate Editor for Ecological Entomology and Biotropica. **Hatcher** is Chair of the Editorial Board for Weed Research. **Johnson** is Associate Editor for Methods in Ecology and Evolution, Heredity and Deciding Editor for the Journal of Evolutionary Biology. **Perotti** is an Associate Editor for Experimental & Applied Acarology, PLoS ONE and Frontiers in Ecology and Evolution. **Murn** is Editor of Vulture News (journal of the IUCN Vulture Specialist Group). **Oliver** is the Review Editor for Frontiers in Sustainable Food Systems, Associate Editor for the Journal of Insect Conservation and Diversity. And **Culham** is Associate Editor for Botanical Journal of the Linnean Society and PeerJ.

In addition to the learned-society roles noted above, EEB staff sit on a diverse range of boards, committees and scientific advisory panels for UKRI, charities and industries involving in funding unit-related research. **Pagel** is on the Science Advisory Board of the Santa Fe Institute. **Gripenberg** and **Oliver** are peer review college members at NERC and **Oliver** is, within Defra and working closely with NERC, leading the coordination of a NERC Strategic Priority Fund Wave 3 bid. **Johnson** has been on the NERC Biomolecular Analysis Facility Steering group. **Venditti** is peer review college member for the Irish Research Council. **Hawkins** is on the UKRI Future Leader Sift Panel.

Outreach and public understanding to benefit society

We actively seek to engage with society as scientists providing information, commentary or synthesis of ideas in ways that enable discussion and exchange. We routinely organise events on campus and in the local community which are very well attended. On campus we regularly organise events in our Botanical Gardens (The Harris Garden) open to the public and school groups. Youth groups are often given tours of our Tropical Glasshouse by EEB staff. We actively work with local schools so that they benefit from the zoological collection in our Cole museum (on average we have 12000 visitors per year including from 8 local schools). Staff in our UoA have also participated in the Reading Pint of Science festival that began in 2018 (**Johnston** and **Johnson**), and in Soapbox Science events (**Gonzalez-Suarez**).

EEB academics have featured in the press over 100 times each year since 2014. For instance, to highlight a few, **Pickles**, took part in a Radio feature called 'Six reasons plants are cleverer than you think' which was aired on BBC Radio 4 and BBC World Service. He also took part in

WOMADelaide, a festival of Music, Arts and Dance, as part of a panel on “Can trees and plants talk, think and heal?”. **Pagel**, regularly talks to the media on issue of evolution, including cultural and language evolution (e.g., Featuring in BBC Radio 4’s Digital Human Series and Word of Mouth), and recently featured in the Independent newspaper in an article called ‘Orthocoronavirinae: What does it mean and which other viruses are in the subfamily?’ Pagel has also given 5 public lectures since 2014, including the Gifford Lectures (Glasgow), and the Darwin Day Provost’s Lecture (New York). **Hawkins** took part in the Radio 4 programme Making History, contributing to an item about plant poisons. **Baker**, an early career fellow, was recently interviewed on BBC Berkshire Radio about newly described fossil mammals and what that means for their evolution more generally.

Three popular science books have emerged from our unit within the assessment period. Two are edited volumes by **Fellowes** and Battey (a retired former EEB member) – ‘30-Second Evolution’ (2015) and ‘30-Second Biology’ (2018). Oliver has written a *THE SELF DELUSION* (2020).

EEB has been successful in promoting its own original research to society and the media. Our work routinely gets covered in the local, national and international media. One highlight was a paper by **Venditti** about the decline of dinosaurs that attracted substantial media attention and changed the way many view dinosaur evolution and extinction. This paper was also in the international top 50 most important publications of 2016 based on Altmetric score (score=2023, in the 99th percentile of all publications).

Academic engagement and uptake: communicating our research

Since REF 2014 EEB staff have organised 15 national and international workshops, seminars and conferences including: EURAAC Congress’s session on Forensic Acarology (**Perotti**, attendance ~300); Gordon Research Conference ‘Unifying Ecology across Scales’ (**Sibly**, attendance ~140). Gene-phenotype associations across evolutionary scales, symposium at The European Society for Evolutionary Biology Annual conference (**Baker**, attendance ~300).

Ten members of our unit have presented 28 keynote/invited lectures at high profile academic conferences or meetings. **Pagel** has been plenary speaker at 4 meetings, including ‘The evolution of innovation: you are not as clever as you think’ at *The Evolution of Innovation: Big Brains or Big Data* held in Cambridge. **Oliver** has presented six, including ‘Understanding climate change impacts using long-term monitoring data: Butterflies as a model system’ at Future of Butterflies Conference, Wageningen, Netherlands. **Perotti** has also given five invited presentations including ‘Trace qualification’ at Security Research NCP Network (SEREN4): Brokerage event, Horizon 2020 topics related to the fight against crime and terrorism held in Paris. **Melero** has presented 3 including ‘Butterflies in the city: ecological filtering of urban landscape’ at the European Conference of Computational Biology held at the University of Jyväskylä, Finland. **Gripenberg** was invited to present at 3 international conferences including ‘Plant enemies as modifiers of tropical forest plant diversity’ at the Annual meeting of the Linnean Centre for Plant Biology, Sweden. **Sibly** has presented at three, including ‘Quantifying uncertainty in the predictions of complex process-based models’ at Progress on novel mathematics and statistics for Landscape Decisions, Isaac Newton Institute, Cambridge. **Venditti** was invited to present ‘Phylogenetic rates, adaptive evolution and evolutionary trends’ at the Systematics Association biannual conference. Oxford. **Hawkins** presented ‘Cultural Evolution and Medicinal Plants’ at the inaugural Plants People Planet meeting at Royal Botanic Gardens, Kew.

Responsiveness to national and international priorities

Oliver has been working extensively at the science-policy interface through a Senior Fellowship (2018-21) secondment with Defra. Oliver is ‘design authority’ for their *Systems Research Programme*, leading a team comprising 8 Defra officers and 5 academic fellows. The role involves applying systems science approaches to inform the design of policies to meet multiple environmental outcomes. Oliver’s role benefits EEB by facilitating new links between UoR researchers and Defra.

Hawkins was a member of a British Pharmacopoeia working group which makes an important contribution to the role of the MHRA in protecting public health by providing quality standards for UK pharmaceutical substances and medicinal products. The DNA Working Group oversaw the inclusion of Supplementary Chapter VII D, “DNA Barcoding as a Tool for Botanical Identification of Herbal Drugs”, which is included in all editions from 2017.

Perotti was invited to contribute to several government consultations, including the Science and Technology Select Committee’s (House of Lords) report, ‘Forensic science and the criminal justice system: a blueprint for change’ in the UK. At the international front, Perotti participated in the Trace qualification round-table, the Security Research NCP Network (SEREN4 Brokerage event, Horizon 2020), on topics related to the fight against crime and terrorism, and the Research and Development Liaison of the Animal Plant Soil Traces (APST) Group advising the European Network of Forensic Science Institutes.