Institution: University of Liverpool

Unit of Assessment: 5 - Biological Sciences

a. Overview

The unit for this submission is The Department of Evolution, Ecology and Behaviour (DEEB), part of The Institute of Integrative Biology (IIB), one of five Research Institutes in the Faculty of Health and Life Sciences. Hence it is a more focused submission than 2008. Research in DEEB is organised around three Research Groups, namely Ecology, Evolution and Genomics of Infectious Disease (EEGID), Evolutionary Ecology (EE), and Mammalian Behaviour and Evolution (MBE). Staff are often members of more than one Group. Groups also incorporate some staff from other Departments (staff not included in this submission) and other Institutes within the Faculty. This enhances fluidity and interdisciplinarity.

b. Research strategy

Significant changes over the assessment period: In September 2009, activity over three Faculties at the University of Liverpool was brought together to form a new Faculty of Health and Life Sciences, in order to organize Institutes and Departments around recognised areas of research strength. This led in 2010 to the creation of five Research Institutes, of which IIB is one. The new structure gives full clinical and scientific coverage, spanning Biosciences, Clinical Medicine, Health Sciences, Dentistry and Veterinary Science in one Faculty.

Over the assessment period, of the three research groups in DEEB, EEGID has broadened its scope to bring local strengths in parasite genomics under its umbrella; EE has formed from smaller research groups in ecology and evolution to enhance cross-fertilisation; and MBE has done the same through the merger of staff from the former Veterinary Faculty and School of Biological Sciences. EEGID and EE operate from the Biosciences Building (main campus). MBE operates from the Leahurst campus (Wirral), where their exceptional animal facility is sited (see 'Infrastructure'), but close collaboration amongst all staff is maintained by MBE's own office in Biosciences, a joint external seminar series, and internal colloquia.

Overall strategy: A defining characteristic of IIB is its breadth, from community ecology to structural biology, whilst focusing its research strategy on key areas of internationally-leading strength. Evolution, ecology and behaviour (DEEB) is one such area, as emphasised by IIB's recent policy of targeted recruitment into this area (4 ECRs, 1 Reader in the last 18 months), also enhancing our retention of the highest-quality staff. Focusing on strengths, but doing so across a broad canvas, is, we believe, the best way to combine critical mass and scientific coherence with interdisciplinarity and flexibility for change. DEEB's interdisciplinarity is also benefitting from investments in other strengths within IIB: genomics, proteomics, bioinformatics and modelling (2 ECRs, 2 SL/Readers, 3 Professors since 2008) and from the outstanding range of life science activity across the University. For example, most DEEB staff make use of IIB's nationally-leading genomics facilities, several now incorporate cutting edge proteomics in their work, and two are key members of the new Centre for Computational Biology and Modelling. The DEEB Research Groups reflect areas of strength that we shall sustain, but within each, our recent recruitment and ever-growing interdisciplinarity are ensuring an on-going evolution of focal areas of research (see below), encouraged by policies of joint-supervision of PhD students and co-application for grant funding: of 27 RCUK or equivalent PI grants won by this unit within the submission period (see also, below) 9 had DEEB Co-Is.

Mechanisms for the development, promotion and dissemination of research: Research Groups meet weekly (MBE) or fortnightly (EEGID, EE). Their roles are to promote research, and sustain and develop an active and vital research culture. They do so by (a) organising journal club sessions monthly, at least monthly, with the introducer role rotating among staff, PGRs and Post-doctoral (PD) staff; (b) providing a venue for PGRs and PDs to give short research seminars on a regular basis, including trial runs of talks to be given at scientific meetings, but also more informal up-dates to solicit group feedback; and (c) 'flying kites' – discussing early stage ideas for new research projects or publications (for example, Paterson's *Nature* paper and Hurst's NERC grant on range expansion both started like this).

In addition, the Groups combine to organise two key activities. The first is a weekly series of seminars, predominantly populated by external speakers, plus an annual internal colloquium to

discuss new research. The second comprises regular sessions for internal review of grant applications. Initially, at least eight weeks before the relevant deadline, applicants present the scientific rationale, excitement and general structure of their proposals to a group of colleagues (usually ten or more). Draft submissions produced in response to feedback are then reviewed by a selection of relevant staff before final submission. The success of this process is evidenced by our accelerating income stream (see 'd', below).

Research is disseminated through publications and attendance at meetings, and also to the general public and user groups. For publications the strategy is similar to grant applications: a culture of internal peer review and a focus on the highest quality journals. All staff and students are encouraged and supported financially in attending national and international meetings. We have a member of staff responsible for external communication, three others responsible for maintaining the Group websites, and a strong record of publicising our work in national and international media. There is also emphasis on student and staff involvement in local meetings and events (SciBar, Café Scientifique etc.), and dissemination to users (e.g. Animal Welfare: Home Office; Disease biology: DEFRA). Student involvement in scientific dissemination was particularly commended by BBSRC in IIB's *Excellence with Impact* Award (2011).

Research Groups' activities and main achievements: There are major strengths throughout DEEB with, alongside accelerating grant income, from the 18 staff submitted, 7 papers in *Science*, 2 in *Nature*, 8 in *PNAS,* 3 in *Current Biology*, 15 in *Ecology Letters* and one in *Nature Methods* (all main authors, all substantive publications, no double counting).

EEGID combines ecological and evolutionary approaches to understand infectious disease, from both fundamental and applied perspectives. Working on a range of systems, including wildlife infections, reproductive parasites of insects, and human microbial pathogens, staff employ a diversity of methodologies: theory, experiments, genomics and fieldwork. The group benefits from Liverpool's acknowledged strengths in infectious disease research, with strong collaborative links with the Faculty's Institute of Infection and Global Health (7 projects) and National Consortium for Zoonosis Research (4 projects). Core research interests are:

Wildlife disease dynamics: Work covers the ecological and epidemiological dynamics of diseases, often zoonoses, in wild rodent populations both in the UK and, with international collaborators, abroad. Such populations also provide model systems for understanding infectious disease dynamics in humans. Recent important advances include a breakthrough description of transmission dynamics in wild populations (*PNAS* Begon #2), methods of quantifying host contributions to disease maintenance in ecological communities (*Ecol Letters* Fenton #2) and elaboration of thresholds for plague persistence in natural reservoirs in Central Asia (*Nature* Begon #3; Begon *PNAS* (2011) 108: 14527-32; *Ecol Letters* Begon #4).

Coinfection: Research focuses on the key questions, translatable to all infections, of how parasite species interact within a host, how host species interact through shared parasites, and how these affect epidemiological and evolutionary disease dynamics. Key recent advances include the first elucidation of microparasite coinfection patterns in a natural population (*Science* Begon #1 with Paterson) and a modelling study exposing shortcomings in current methods for studying co-infections and suggesting solutions to these (*Ecol Letters* Fenton #1).

Coevolution: A particular focus is on host-parasite coevolution, a key evolutionary force implicated in, for example, population dynamics, the evolution of polymorphism, sex and virulence, and speciation. A recent, important advance was the first laboratory test of the Red Queen Hypothesis (*Nature* Paterson #1 with Fenton), which used a novel combination of experimental evolution and next-generation DNA sequencing.

***Parasite genomics*:** We adopt modern genomic approaches to study the evolution of host resistance and parasite infection. In collaboration with the Centre for Genomic Research, we lead the sequencing, assembly and annotation of major genome projects on parasites, vectors and hosts. Recently, we have uncovered key genes underpinning resistance to a range of pathogens in natural environments (*PLoS Genetics* Paterson #2 with Begon) and the evolution and genetic diversity of amoebic dysentery (Paterson *Genome Biology* (2012) 13:R38).

Looking forward, PGR recruitment to this and all research groups will be substantially increased, and training enhanced, through the new NERC DTP (see below). We are now evolving rapidly in our development of mathematical models, with the arrival of Cornell, and in the application of sophisticated computational methods to our large data sets, with the arrival of Falciani (IIB, UoA1; already collaborating with Begon and Paterson), and with the recent award of

a 'Big Data' grant from NERC. We expect to see intense activity and rapid progress in the next five years in ecological immunology and in the role of microbial symbionts in animal ecology and evolution. We are in the vanguard, internationally, in both areas. We will increase our direct involvement with public health authorities, building, for example, on Begon's recent membership of the WHO group advising the government of Fiji on leptospirosis control.

EE focuses on the evolution of organisms within the context of their environment to better protect biodiversity and mitigate the effects of environmental change. Activity can be described under four main headings:

Evolutionary ecology of colouration and defence: Behavioural and post-genomic studies are combined to understand anti-predator adaptations. Work on the peppered moth identified the locus responsible for melanism, and demonstrated a convergent trajectory to evolution through selection acting at genomic hotspots (*Science* Saccheri #1; *PNAS* Saccheri #2 with Watts). Research also resolved the paradox of why the defensive benefits of group living are so weak by demonstrating that group life is associated with reduced individual investment in defence (*Ecol Letters* Speed #3), showed for the first time that weakly defended prey species that mimic better defended species are parasitic (*Ecol Letters* Speed #2), and elaborated the evolution and dynamics of cryptic masquerading prey (*Science* Speed #1; *PNAS* Speed #4).

Non-Mendelian inheritance, symbionts and evolution: Work aims to understand the importance of meiotic drive and microbial symbionts as evolutionary and ecological drivers. Key results include experimental evidence that female monandrous reproductive systems increase a species' susceptibility to extinction from meiotic drive (*Current Biology* Price #2 with GHurst), and, reciprocally, that female remating rates can evolve in response to meiotic drive (*Science* Price #1 with Lewis, GHurst). We provided the first evidence that sex ratio distorter-host interactions undergo evolutionary chases, with the spreading of a distorter followed by spread of the host suppressor (*Current Biology* GHurst #1). We showed that almost twice as many species of insects carry inherited symbionts as had been thought, and that consequent sex ratio distortion can be infectious between species in natural populations (*Ecol Letters* GHurst #2; *BMC Biology* GHurst #3). In a recent line of research, gut symbionts have been established as important in determining insects' ability to recognize kin (*ISME J* Lewis #1).

Biodiversity conservation and climate change: We use both field and laboratory approaches to predict and mitigate biodiversity loss, and to improve land management strategies for conservation. Key results include the demonstration that retaining biodiversity during agricultural production is better achieved by a mix of nature reserve/intensive farming than one of intensive/organic farming (*Ecol Letters* Hodgson #1), and that connectedness of habitat patches *per se* serves to stabilize predator-prey interactions in communities (*Ecol Letters*, Montagnes #1). In terms of practical conservation of individual species, it has been demonstrated that behavioural estimates of reproductive success perform poorly as fitness proxies in natural populations (*Ecol Letters* (2011) Thompson #1 with Watts), while at a fundamental level, it was demonstrated that the controversial neutral theory of biodiversity can be revitalised by incorporating protracted speciation (*Ecol Letters* Cornell #2).

Evolutionary adaptation and climate change: We combine genetic, phylogenetic, experimental and meta-analytical approaches to understand functional evolution, especially in relation to climate change. Key results include showing the evolution of elevated myoglobin net surface charge in all lineages of living elite diving mammals, and inferring the diving capacity of extinct species representing stages in mammalian land-to-water transitions (*Science* Berenbrink #1), the demonstration that the temperature-size rule for metabolism is especially strict in aquatic species (*PNAS* Atkinson #1), that thermal effects on metabolism vary with lifestyle (*Ecol Letters* Atkinson #2), and that even freely mixing marine microorganisms retain genetic signatures of past climatic fluctuations (*PNAS* Watts #1 with Montagnes).

Looking forward, we will benefit from the *c*£100k investment in our main, shared laboratory (2014 budget) to upgrade insect handling and molecular facilities, and from continuing major investment (£2.5M by 2016) in post-genomic technologies that we are using increasingly to better understand adaptive responses to changes, for example, in climate, pesticides and parasites. Fruits of nascent collaborations between conservation biologists (Hodgson, Cornell) and geneticists (Saccheri, Paterson) will help us become international leaders in developing predictive models for biodiversity conservation in changing (not static) landscapes. Deep involvement in the Buxton Climate Change project (Whitlock), which is likely to generate the best long-term data on

grassland resilience to climate change in Europe, will, by its essence, bear fruit increasingly in the longer term.

MBE supports research spanning interlinked areas within the fields of animal behaviour, behavioural ecology, animal welfare and management. Work is multi-disciplinary, integrating behaviour, ecology, biochemistry, physiology, proteomics, structural biology and molecular genetics, with an underlying evolutionary approach. Core research interests are:

***Chemical Communication*:** We integrate behavioural and molecular aspects of mammalian scent communication in collaboration with Beynon's Protein Function Group (IIB, UoA6). Current interests include: assessment of mate quality, heterozygosity, genetic compatibility and kinship; influences on mate choice and cooperation; pheromones as potent stimulants of associative learning. Recent key advances include identifying 'darcin', a new sex pheromone in mice that stimulates female attraction and memory (*Science* JHurst #3) and the ability of mice to assess individual heterozygosity through major urinary proteins (*Current Biology* JHurst #4 with Stockley). Building on fundamental advances, we are developing new strategies for rodent pest control based on using scent signals to manipulate rodent behaviour (BBSRC sLoLa).

***Reproductive Strategies**:* We investigate how reproductive competition influences phenotypic diversity. Current areas of interest include mechanisms and evolutionary consequences of pre- and postcopulatory sexual selection, sexual conflict, and female competition. Recent important work has shown how rapid evolution of mammalian seminal fluid proteins is linked to sexual selection (*Mol Biol Evol* Stockley #1 with JHurst).

***Animal Welfare**:* We apply our understanding of behaviour and evolution to advance understanding of animal welfare. Current interests include methods that reduce anxiety in laboratory rodents; strategies to improve experiment reliability; novel approaches for improved welfare assessment and monitoring. Our recent NC3Rs-award winning work demonstrated new handling methods that can substantially reduce handling anxiety in laboratory mice (*Nature Methods* JHurst #1), leading to widespread changes in practice (see 'Impact').

Looking forward, the success of the BBSRC sLoLa (JHurst & colleagues) will be directed into broader collaborative ventures required to address the global problems of rodent pests threatening food security and biodiversity. Through building up a network of Stakeholders (pest control companies, government agencies, NGOs) and research groups across the EU, we are now ideally positioned to create large-scale ERC and Horizon 2020 bids to broaden application of this research across Europe, and, using special funding programs, build links with countries where the impact of rodents is greatest (e.g. Indian subcontinent, Brazil). MBE will also take the lead in incorporating semiochemical control into integrated pest management strategies, recognising the critical need to include specialists in the built environment and agriculture to increase effectiveness. We will continue to gain RC funding for fundamental research that will provide new approaches to improve breeding, welfare and conservation of managed animals, explored through close contacts with e.g. Chester Zoo, Genus plc, NC3Rs and RSPCA.

c. People, including:

i. Staffing strategy and staff development

Staffing strategy and staff sustainability in the unit: Our three Research Groups have been formed around demonstrable areas of great strength. Our strategy is to build on these while recognising that all scientific disciplines evolve in response to scientific and technological developments. Hence we have supported existing strengths by recruiting in the areas of non-Mendelian inheritance (Price), microbes in animal biology/ecology (Lewis), genetic diversity and community function (Whitlock), mammalian behaviour (Bro-Jorgensen), biodiversity conservation (Hodgson) and modelling both biodiversity and host-parasite dynamics (Cornell).

Our guiding philosophy is one of collegiality. All staff (including those not submitted here) are valued members of the team. The distribution of teaching and administration is strongly directed by research profiles, but all staff are expected to contribute in all spheres and all do. A very high proportion of grants submitted represent collaborations between members of DEEB, and 10 of our highest impact publications (above) had DEEB co-authorship. This enhances multi-disciplinarity and further cements our collegial ethos.

A strength of DEEB is that it comprises staff at all career stages: 5 Professors, 5 Readers, 4 Senior Lecturers, 4 Lecturers, and 3 Tenure-track (TT) Fellows that we fully intend to give tenure (recruited following a wide external search, two with NERC Fellowships already). Hence, both

progression and sustainability are being maintained. Within the assessment period there have been four promotions from L to SL, four from SL to Reader, and one from SL to a Chair. Brockhurst moved from L to Reader and thence to a Chair at York. All are testament to our staff's own abilities, our mentoring, and to our future as well as our present healthy state. This supports, too, our view that while strategic appointments to Chairs are justified, the best route to a sustainable, flexible, collegial and ultimately powerful group is to recruit young stars (such as our TT Fellows) and promote from within.

All non-professorial staff, including Fellows, have a mentor who provides regular advice on strategies for grant applications, paper submissions and on career progression, meeting frequently and informally outside the formal review process (PDR – see below). The mentor for post-docs is typically the PI on the supporting grant.

Early Career Researchers: Beyond IIB and University policies, our collegial ethos is especially relevant to ECRs and post-docs. ECRs begin with a light teaching and administrative load (e.g. 4 lectures and no administration in the first year), with existing staff taking on these tasks, which is then gradually increased to standard levels over a 3-5 year period. We believe it is important that ECRs have intellectual space to establish a research programme, but equally important to incorporate this into DEEB's (and IIB's) wider programme and ensure that ECRs develop a balanced portfolio to support career progression. Five staff within DEEB benefitted from this policy as ECRs, winning RCUK grants within three years of appointment, including Hodgson, recently (NERC KE grant within one year). Post-docs moving on to Faculty positions since 2008 include Duron (Montpelier), Evans (Anglia Ruskin), Jackson (Aberystwyth), King (Oxford), Lowe (Exeter), Telfer (Aberdeen) and Thom (Plymouth).

Broader University policies: The University received the HR Excellence in Research Badge from the European Commission (2011). It is a signatory to the Research Concordat. An Implementation Group meets frequently to track progress; as part of its work, the University completed the CROS and PIRLS surveys and is responding to issues raised. It is embedding the national Researcher Development Framework (RDF) into current structures. In supporting **equality and diversity**, the University gained the Athena Swan Bronze Award in 2009. IIB are currently applying for a Silver Award. Each member of staff (including fixed term researchers) participates in the University's **Professional Development and Review** (PDR) process at least annually, underpinned by a Portfolio of Activity, recording the full range of staff activity and informing discussions on workload and development. PDRs also inform resource planning and provide the evidence base for reward or promotion cases. A **Postdoctoral and Early Career Research Staff Programme** provides research-specific development and also develops transferrable skills in early career researchers (including fixed-term staff). Additional research-related training courses and workshops are available through the University's **Centre for Lifelong Learning**. We proactively seek redeployment opportunities for fixed term staff, leading to an extension/redeployment rate for researchers of 68% (January 2008-March 2012). All staff are eligible for maternity, paternity and adoption leave. In DEEB, none of their duties are 'held over' until their return. All academic staff are eligible to apply for research leave: normally one semester of research leave after no fewer than five semesters (or equivalent for part-time staff). Recent recipients in DEEB include Atkinson (2 REF papers as a result), Begon (successful Wellcome Trust grant), Montagnes (2 REF papers, new collaboration in China established), Plaistow (successful NERC grant), and Watts (3 grants, one REF paper).

ii. Research students

Research students work in research laboratories shared between cognate groups. Thus, they work in a vibrant and supportive environment with post-docs, RAs, technicians and visiting research fellows, broadening their research experience and providing an excellent environment for developing good interpersonal and team-working skills. Each PGR has their own desk and computer networked to the University IT and library facilities in an office area separate from the laboratory space. The Institute's dynamic Postgraduate Student Society runs an active programme of social events, academic talks, workshops, networking and career events throughout the year, also providing opportunities for students to enhance their employability.

All students have at least two supervisors, fostering interdisciplinarity and broadening their training and experience. Students also have two independent assessors (one subsequently Internal Examiner) who provide quality assurance of student progress and of supervision. In Years

1 and 2, all students produce a report on their research during the year that is discussed in a *viva voce* examination with the assessors, testing communication skills and providing training for the doctoral viva. These reports monitor development of scientific writing skills; the Year 2 report contains a doctoral thesis plan. Assessments in Years 3 and 4 focus on tracking the thesis plan, presentations at conferences and/or submission of manuscripts for publication.

The University online system for monitoring progress gathers information from the student, supervisor and assessors for review at Institute and Faculty level before re-registration for the next year is approved. Students maintain an online Personal Development Record (PDR) until thesis submission, documenting formal progress meetings with supervisors (minimum 8 annually), and recording training and generic activities following QAA and RC guidelines. Concerns identified by a student can be discussed further with their assessors, outwith the yearly formal meetings, or the Institute Director of Postgraduate Research (IDPR). Students undertake at least 90 credits of modular training prior to submitting the doctoral thesis.

From 2014, PGR training will be significantly enhanced. With Sheffield, York and NERC's Centre for Ecology and Hydrology, we have been awarded one of 15 NERC Doctoral Training Partnerships (DTPs) for our biologically-focused program Adapting to the Challenges of a Changing Environment (ACCE). This will support 22 new Studentships p.a. of which Liverpool (largely DEEB) can expect *c*33%. ACCE has been designed to reduce institutional boundaries and build a strong PDR community with no pre-determined allocation of Studentships between partners, a 50% target for cross-institutional co-supervision, non-academic placements, full cohort training events, peer-to-peer support, a 40% target for CASE projects, and a flexible training program tailored to each student's needs. ACCE students will experience world-class training enabling them to become leaders of the next generation of environmental scientists.

The success of our policies and procedures is evidenced by our institutional PhD completion rates being amongst the highest in the UK in HEFCE (2012) and THES (2010) reports. Rates within DEEB exceed these at 89% over 5 cohorts (n=39). PGRs from DEEB have been awarded prizes for both science (Zoological Society of London; Royal Ent Soc) and writing (Royal Ent Soc; New Scientist/ASAB). Many graduating from 2008 have made rapid progress in their scientific careers: 16 have PDRAs, Lemaitre and Ramm have independent Fellowships; Behnke (Harper Adams), Hassall (Leeds) and Naim (Malaysia) have Lectureships.

d. Income, infrastructure and facilities

During the submission period, our staff won **grant funding** to the value of £27.2M from RCUK, major charities etc: 30 as PIs (value £12.4M) and 19 as CoIs (£3.2M of CoI funding coming to staff in DEEB) with no double counting. This is far higher than metrics on 'spend', highlighting recent substantial acceleration (smoothed 2-year averages for PI grants, 2008-13: £0.84M, £1.63M, £2.24M, £4.45M, £3.35M). NERC and BBSRC are our major funders. Judged by NERC's Student algorithm, Liverpool was ranked joint-fifth for grants and fellowships amongst biological sciences departments nationally. DEEB received 8.5 BBSRC DTP/CASE funded Studentships during the assessment period. The NERC DTP (above) will further increase PGR income. For income generally, we are determined to sustain our upward trajectory. With five new appointments in the last 18 months and only two staff leaving in the assessment period (one research-inactive), we are confident of achieving this.

DEEB benefits from an exceptional range of **facilities and equipment** within IIB.

There is a dedicated 40-place **multi-user laboratory,** including a range of small and large constant temperature rooms and access to extensive aquarium and glasshouse facilities.

The **Centre for Genomic Research** (CGR) is the core provider for MRC and NERC of the latest 'next-generation' DNA sequencing and robotic handling technologies. Its 20, mainly postdoc staff support a range of projects within this submission, including those using genome and RNA-Seq for studying infectious disease, evolution and environmental biology. It has received ~£14.2M income since 2008 (not counted elsewhere here) comprising RCUK core funding and project grants from RCUK, TSB, EC, charities and industry.

Reflecting its priorities, IIB has also funded a new **insect model organism laboratory** ('*Drosophila* lab') with piped CO_2, fluorescence microscopy, negative pressure, a dedicated insect media prep room, two constant temperature rooms, and food storage refrigeration.

A **wild rodent behaviour laboratory** at the Leahurst campus (established by a Wellcome Trust SRIF award to JHurst, Begon and others) provides unique custom-built facilities for manipulation

and behavioural analysis of wild and laboratory rodents, with 1000m^2 of indoor controlled environments and behavioural laboratories, 4000m^2 of outdoor enclosures, and a small field laboratory. There are 17 environmentally controlled rooms indoors (three with Cat 3 protection), all with video tracking and remote recording facilities, a custom-built system for tracking rodent movements through tunnel detectors in 16 interlinked indoor enclosures (supplemented by BBSRC SREI grant, £98K, to JHurst, Stockley), and in development, a similar system in semi-natural outdoor enclosures (£230K of BBSRC sLoLa to JHurst).

Ness Botanic Gardens provides dedicated outdoor research space on the Wirral peninsular, allowing us to run both small- and large-scale experimental studies that would be impossible within a lab environment. It is supported by an automatic weather station, a de-ionised water source, and technical and administrative support from Gardens staff. The Gardens also house a unique array of 48 x 3000L aquatic mesocosms used to investigate the impact of global warming and other environmental manipulations on aquatic ecosystems.

The new **Centre for Computational Biology and Modeling** is a cross-faculty development for the application of deterministic and stochastic modelling techniques in the biosciences, with links to maths, engineering and physics. Cornell has recently been recruited as Deputy Director. Particularly relevant to this submission is statistical data processing of 'omics data, and the analysis of epidemiological, population, evolutionary and environmental models.

Work within DEEB increasingly makes use of other major IIB facilities. These include a state-of-the-art **proteomics suite** (~300m^2), offering access to ~15 mass spectrometers, each equipped with chromatographic systems for protein separations and robotics for sample handling, the **NMR Centre for Structural Biology**, equipped with three state-of-the-art NMR spectrometers (800, 600 and 400MHz), and the **Centre for Cell Imaging**, with 7 confocal/ luminescence/two-photon and photothermal microscopes. Each comes with a full complement of computational infrastructure and expertise, and specialist postdoctoral cover.

Finally, at the Faculty level, further externally funded Centres include the **National Consortium for Zoonosis Research** that Begon (initially Deputy Director) was instrumental in establishing, and under whose umbrella four collaborations within DEEB are proceeding.

To maximise efficiency and impacts of University investments, a **Technology Directorate** oversees the integrated creation, development and access of all core facilities across the Faculty. Its equipment inventory is available through the N8 Shared Equipment Database and it is contributing to the on-going project to encourage cross-HEI sharing of major assets.

At the University level, extensive research investment continues. A postgraduate study room, for example, has been created in the Harold Cohen Library. For Computing Services, the University began in 2009 a 5 year, ~£5M investment in its data network. The University also continues to work closely with Net North West who manage our wide area network connections and in particular our high speed (20Gbps) resilient links to the JANET network.

Policy and practice in relation to research governance: In 2009, a Research Governance Working Group (RGWG) was formed to pull together all relevant research governance policies from around the University. The RGF Toolkit (implemented in July 2011) facilitates research governance approval for staff at the University by streamlining this into one easy step-by-step process, directing researchers to relevant departments and policies.

e. Collaboration and contribution to the discipline or research base

Indicators of wider influence

Several staff have held positions of influence and responsibility in major Learned Societies. Begon has been Vice President, and GHurst and Thompson both Council members, of the British Ecological Society. JHurst has been President, and Stockley a Council Officer, of the Association for the Study of Animal Behaviour. Montagnes has been Vice President of the International Society of Protistologists. Watts has been Meetings Secretary for the Marine Biological Association of the UK and on the Conservation and Education Committee of the North of England Zoological Society. Fenton is Deputy Head, and Begon a Board Member, of the (now pan-European) British Ecological Society/British Society for Parasitology Special Interest Group on "Parasite and Pathogen Ecology and Evolution".

For the Research Councils, Begon sits on NERC's Science and Innovation Strategy Board. JHurst sits on the BBSRC Appointments Board, the BBSRC Basic Bioscience Underpinning Health Strategy Advisory Panel, previously on the BBSRC Healthy Organism Strategy Advisory Panel, is

Chair of the BBSRC Animal Welfare Steering Committee, and was a Board member of the National Centre for the Replacement, Refinement and Reduction of Animals in Research (NC3Rs). Paterson is node head for NERC's Biomolecular Analysis Facility. GHurst and Paterson have recently been selected as members of NERC's peer review Core Panels.

Fellowships and awards

As well as Fellowships to Atkinson (NCEAS USA, Leverhulme), GHurst (Leverhulme), Price (NERC) and Whitlock (NERC), Begon received the Marsh Award from the British Ecological Society in 2009 for "his world leading contribution to our science through advancing our knowledge of population dynamics, density dependence and host-pathogen dynamics", GHurst won the Scientific Medal of the Zoological Society of London in 2009 for "his work on the evolutionary ecology of animal-microbe interactions", JHurst won the NC3Rs Prize in 2010 for "excellent research published in the last two years that has the greatest potential to reduce the number and suffering of animals used for scientific purposes", and Lewis won the Japan Society for the Promotion of Science (London) Furusato Award in 2011.

Participation in the peer-review process (for journals, members of Editorial Boards)

Staff throughout DEEB take their peer-reviewing responsibilities seriously, with the majority acting for the NERC Peer Review College (Begon, Cornell, Fenton, GHurst, Paterson, Price, Saccheri, Speed, Stockley and Watts). Most are also on Editorial Boards (Atkinson, *J Therm Biol*; Begon, *Proc Roy Soc (Lond) B*; Berenbrink, *J Comp Physiol B*, *Marine Gen*; Cornell, *PloS One*; Fenton, *J Anim Ecol*, *Parasitology*; GHurst, *BMC Evol Biol*, *J Evol Biol*, *BMC Microbiol* (guest Editor); Montagnes, *J Plankton Res*, *J Euk Microbiol*; Paterson, *J Evol Biol*, *Mol Ecol*; Price, *Ecol Evol*; Speed, *BMC Evol Biol*; Stockley, *Evolution*, *Phil Trans Roy Soc (Lond), B* (guest editor); Thompson, *Ecol Ent*; and Watts, *Biol Cons*). Furthermore, several staff have taken on the responsibility of ***Journal Editorship*** (GHurst, *Heredity, Am Nat*; Montagnes, *Marine Biol Res*; Saccheri, *Heredity*; Speed, *Anim Beh*; Stockley, *Anim Beh*).

In addition, Begon sits on the Royal Society International Joint Projects Grants panel and was NERC representative on the ESEI panel; Berenbrink has been an International member, Grant Evaluation Group of the Natural Sciences and Engineering Research Council of Canada; JHurst was Deputy Chair of NC3Rs grant assessment panel, and sat on NC3Rs Strategic Award and EU ANIHWA panels; and Stockley chairs the ASAB Grants Committee.

International academic collaboration

Out of 18 staff members, 17 submitted have tangible, active international academic collaborations (grant co-holders or principal co-authorship of papers in major journals). Notable amongst these are Atkinson's collaborations in the USA on the 'metabolic basis of ecology' that led to his taking up two Fellowships there and Chairing a Gordon Research Conference on the topic in 2010. Begon's work on zoonotic infections in wild rodents has been supported by a Wellcome Trust grant with colleagues in Kazakhstan, Netherlands and Australia and an NIH grant with colleagues in Brazil and the USA. GHurst sat on the Management Committee of EU COST action FA0701 (Insect symbiosis) and was Leader of Working Group 3 of the same mission. Montagnes has four years of collaboration on aquatic ecology and ecological theory with three independent institutions in China, stimulating international exchanges in both directions amounting to 4 man-years of exchange in total (Staff and PhD students). Speed has had highly successful NERC grant-funded collaboration with Prof. J. Mappes, University of Jyväskylä, Finland, using their specialist bird-behaviour facilities. Watts was awarded two grants by the Finnish Academy to work with colleagues at the University of Jyväskylä, and is a key member of the Nordic PRODIVERSA (protist population genetics) network.