Institution: University of Aberdeen

Unit of Assessment: 6 - Agriculture, Veterinary and Food Science

a. Overview

The University of Aberdeen is an internationally recognised centre of excellence for research addressing the global challenges of food security, environmental change and environmental impacts, as evidenced by our 22 (20.4 FTE) academic staff over the REF assessment period having published >520 peer reviewed publications with an average 14.6 citations per publication, spent £16.3M of competitively acquired funding, graduated 110 PhD students, and collaborated with >500 Institutions. Our staff, outstanding facilities and research strategy all shape a research environment that serves as a magnet for recruitment, delivers world-class research and attracts funders, collaborators, students and employers. The research described in this submission is co-ordinated through the Biological Interactions in Soil (BIS) programme (led by **Johnson**) of the Institute of Biological and Environmental Sciences (IBES) within the School of Biological Sciences (SBS). A distinctive strength of our approach is the critical mass formed through integrating our complementary expertise (soil science, plant science, microbiology, biogeochemistry, ecosystem modelling, environmental impacts and global environmental change), across scale (laboratory to field) and geography (high latitudes, temperate and tropical systems). BIS research is central to the development and activity of the University of Aberdeen's Institutional themes in Environment and Food Security (Director; **P Smith**), **Energy** (BIS main contacts **J Smith**, **Hastings**) and the North (BIS main contact **Woodin**) that cut across the traditional University structure of Colleges, Schools and Institutes with the purpose of fostering inter- and cross-disciplinary research and teaching. Within BIS the main research activities are encapsulated in two groupings: (i) Environmental Change and (ii) Plant-soil-microbe Interactions, with several staff contributing to both.

Understanding and quantifying Environmental Change and devising and testing mitigation strategies are drivers of our research encompassing a suite of scales, biomes and organisms, through application of cutting edge techniques. We have brought together interdisciplinary teams to understand the causes and impact of climate and environmental change, challenges of food security, environmental sustainability and pollution. This includes the disciplines of environmental biogeochemistry (**Norton**, **Teh**, **Baggs**), soil and water remediation (**Paton**, **Hallett**), global environmental and climate change (**P Smith**, **J Smith**, **Hastings, Hillier**), ecosystem (natural and managed) processes (**Woodin**, **van der Wal**, **Johnson**, **Teh**), sustaining soil carbon stocks (**Woodin**, **Robinson**, **P Smith**, **J Smith**), mitigating greenhouse gases (**Baggs**, **Teh**, **P Smith, J Smith**) and stabilising and regenerating vulnerable soils (**Hallett**).

The Plant-soil-microbe Interactions group adopts cutting edge technologies (genomics, proteomics, molecular, imaging, mass spectrometry) to characterise, quantify and understand how we can best capitalise upon the interface between the functions of plants, microorganisms and ecosystem processes in a range of biomes, to enhance productivity, ensure sustainability and manage the future of ecosystems for resilience to change. This includes the manipulation of plant genomics to understand response to the surrounding environment (**Salt**), the role of plant community structure in determining soil archaeal, bacterial and fungal communities (**Johnson**, **Baggs**, **Woodin**, **Burslem**, **Prosser**, **Nicol**, **Gubry-Rangin**), plant regulation of rhizosphere processes (**Johnson**, **Baggs**), understanding the microbial contributions to soil and water system health (**Prosser**, **Nicol**, **Paton**), measuring the transmission of human pathogens in soil (**Strachan**), demonstrating the importance of novel microbial groups and processes in soil nitrogen cycling (**Baggs**, **Prosser**, **Nicol**, **Gubry-Rangin**), plant/fungal symbioses and pathogen resistance (**Woodward, Taylor, Johnson, Strachan**), plant (crop) productivity and nutrition (**Salt**, **Price**, **Norton**, **Robinson**), and species coexistence (**Burslem**, **Johnson**, **Taylor**).

Prominent examples of our research:

(i) **Salt** has recently provided new insight into Darwin's 'abominable mystery' - what drove the massive diversification of flowering plants in the mid-Cretaceous? By identifying the enhanced ability of polyploid plants to tolerate elevated soil salinity he has provided a potential explanation for the role of genome duplication in this diversification (Chao et al 2013, *Science*).

(ii) Paradigm shifting research by **Prosser**, **Nicol** and **Gubry-Rangin** has demonstrated that thaumarchaea undertake autotrophic oxidation of organic ammonia, not inorganic ammonia, in low pH soil, which has significant implications for soil management to lower nitrogen loss (Stopnišek et al 2010, *Appl Environ Microbiol*; Zhang et al 2010, *PNAS*; Gubry-Rangin et al 2010, *FEMS Microbiol Ecol*).
(iii) **Price** and **Norton**, using rice as a model crop, work at the cutting edge of research on the relationship between the genotype and its environmental interaction with a focus on traits that can be manipulated to reduce water use and the accumulation of grain arsenic (Zhao et al 2012, *Nature Comm*; Norton et al 2012, *New Phyt*).
(iv) **Johnson**, in collaboration with the James Hutton Institute (JHI) and Rothamsted Research, has shown that chemical signals produced in response to aphid attack by bean plants can be transmitted below ground via common fungal mycelial networks to neighbouring uninfected plants, enabling them to produce chemicals that repel aphids and attract parasitoid wasps, which kill aphids (Babikova et al 2013, *Ecology Letters*, recommended for Faculty 1000 Prime). This necessitates a re-definition of our understanding of the regulation of multi-trophic interactions.

b. Research strategy

The BIS research strategy is contained within the SBS strategic plan (teaching, research and administration) which for research aims for the School to rank in the CUG top 12 Biosciences departments (research assessment) in the UK by 2018 (currently ranked 21st for 2014). The strategic plan is updated annually, drafted by the SBS executive group (Chair, **Baggs**), research Programme leaders (BIS, **Johnson**) and teaching committee, before wider consultation to all SBS staff and research students, Head of College, College Director of Teaching and Learning, College Director of Research and Vice-Principals for Research and Knowledge Exchange. The research strategy is centred on enhancing external research grant income, research student numbers, output citations, facilities and partnerships with top international institutions. The associated operating plan includes new opportunities for staff development, identified areas for BIS new appointments (environmental biogeochemistry, process modelling and environmental genomics/transcriptomics), ensuring access to laboratory space and facilities, disseminating information on national and international research opportunities, and allocating funds to support activities, for example innovative research projects, short exchange visits to other labs, and pump priming grant applications. For BIS the strategic aim is to consolidate our research and teaching around the Environmental Change and Plant-soil-microbe Interactions groups and foster a setting where academics and students can work with external stakeholders to provide solutions to address environmental stewardship and food security issues, from blue-skies thinking to policy relevance.

Achievement of strategic aims: Since 2008 BIS has engineered a concerted shift in focus of research questions from those in the more esoteric disciplines of soil and plant sciences to ones that reflect the more immediate questions of the end-user and funding community in relation to the global challenges of environmental change and food security central to national and international research and policy agendas over the next 30-50 years. This has been achieved through targeting of new academic staff appointments and independent research fellows, the establishment of lectureships for these research fellows, increasing and diversifying our funding base, targeting publication in the strongest journals, evolving and enhancing strategic partnerships, and investment in infrastructure and state-of-the-art facilities. We have established and grown strategic alliances of excellence, increased our international collaborations (e.g. supported by £2.9M EU spend) and attracted partnerships of excellence with other leading national and international institutions and with industry.

Examples of achievements:

(i) Feeding BIS research into policy agenda. The Environmental Change group is one of 16 partners (**P Smith**, Science Director) in ClimateXChange, a Scottish Government Centre of Expertise focused on providing solutions for adapting to climate change and reducing emissions. This Centre provides the evidence base for Scottish Government policy and works closely with the UK Committee on Climate Change, UK Climate Impacts Partnership, Living With Environmental Change (LWEC), the UK Energy Research Centre and the Met Office. BIS researchers benefit from sharing of the latest data and research insights coming forward from this Centre.

(ii) Strategic partnerships. The Plant-soil-microbe Interactions group has been central in the

conception and delivery of the Scottish Food Security Alliance-Crops (SFSAC; **P Smith**, **Baggs** on Directorate); a bringing together of complementary research excellence in crop science (University of Dundee, JHI), soil science (JHI, BIS), environmental modelling (BIS, JHI), plant-soil interactions (BIS) and nutrition (RINH, University of Aberdeen) to focus on optimising resource use, improving nutritional quality and safety in the food chain, assessing the impacts of farming on environmental security, and harnessing the productive potential of diverse landscapes. This alliance helps raise the visibility of food security research in Scotland and is linking with the food industry, e.g. through Scotland Food and Drink. Collaborations between both BIS groups (**Johnson**, **P Smith**, **Baggs, Woodin**) and the Hawkesbury Institute of the Environment (University of Western Sydney) have led to a joint PhD programme, in which PhD students spend their second year at the reciprocal University, and graduate with a joint degree. This is being extended to encompass exchange of postdoctoral researchers and undergraduate project students. These examples of achievement of BIS' strategic partnership objective (national and international) have direct benefits to BIS researchers arising from access to, and investment in, collective facilities, joint research studentships, targeted resourcing for pump-priming, enhanced critical mass to attract further partnerships with world leading Institutions and collaborations with the best scientists, as well as a collective voice in shaping of funding and policy agendas.

(iii) Advancing and capitalising on technology. The dot.rural Digital Economy Hub led by the University of Aberdeen is a £12.4M RCUK programme with support from the Scottish Funding Council for an innovative cross-disciplinary collaboration between academia, industry, government/public sector, non-governmental organisations and community organisations. Different disciplines are integrated to target new areas of research centred on the use of digital technology. A major component of this programme managed by **Van der Wal** (Environmental Change group) is exploring how digital technologies can help communities transform the way they manage, use and conserve natural resources.

Aim and goals for the next five years: We will continue the above trajectory, building critical mass and infrastructure for long-term growth in Environmental Change and Plant-soil-microbe Interactions. Our five year goals are focused on: (i) a 25% increase in, and diversification of, external research grant income (e.g. Government, industry, overseas research councils), (ii) a move from three independent research fellows in five years (2008-2013) to five within the next five years with a view to conversion to lectureships where we have identified budget lines, (iii) an augmented postgraduate research student body, targeting an average supervision group of four per member of staff, (iv) publishing and editorial roles in the highest profile international journals, (v) a rolling plan of upgrading current equipment in the Cruickshank analytical laboratories and mass spectrometry suites, and investment in cutting-edge analytical facilities (e.g. X-ray computed tomography coupled to isotope ratio mass spectrometry; estimated £250k and technical support) funded through University strategic investment funds and RCUK grants, (vi) capital investment in a new science building to open in 2018 shared with the College of Physical Sciences (University fundraising and strategic investment funds; current estimate £72.5M), (vii) consolidation of our extensive collaborations into formal partnerships with leading international Institutions, for example fostering existing collaborations with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Chinese Academy of Sciences (CAS), the Institut National de la Recherche Agronomique (INRA) and the Wageningen University and Research Centre (UR), building critical mass integrating the sciences and socioeconomics underpinning food production, with anticipated financial commitment ~£50k p.a. from each partner, (viii) driving forward impact through formal and informal collaborations with developing country Institutions (e.g. Universities in India, Nigeria), (ix) enhanced collaboration with industry and other non-academic stakeholders, and (x) building on our engagement with funding bodies and government, strengthening the translational pipeline from science to policy, and informing leadership of UK and EU strategy.

Future investment for BIS (e.g. University, Scottish Government and donors) will be focused on building partnerships, multidisciplinary collaborations, fostering links with industry and government, and building cutting edge facilities, all in response to national and international priorities in ecosystem stewardship, food security, environmental change and sustainability, and environmental technologies. *Examples of specific areas already targeted for investment:*

(i) Strategic partnerships. SFSAC (see above) will be grown through investment in joint facilities,

international partnerships (e.g. with the Wageningen UR, INRA, CAS, CSIRO), links with industry through Scotland Food and Drink, student industry placements and staff secondments.

(ii) Translational pipeline through a multidisciplinary approach. The University-prioritised Environment and Food Security (EFS) Theme (**P Smith**, Director) is a springboard through which different disciplines can integrate to magnify their impact, providing added value, capacity building and new synergies. It presents a vehicle for dialogue between science and end-users (e.g. government, NGOs, industry, private sector and communities) to identify and address relevant questions, and translate science into integrated evidence to help inform policy decisions to deliver real economic and societal impact. The EFS theme will also be used as a vehicle for closer alignment of BIS research and our spin-out companies Remedios Ltd and EPONA technologies (**Paton**, Director), to help ensure that they remain at the forefront of the environmental technology industry and to be responsive to their user base. BIS investment will be in the form of a cohort of cross/multidiscipline based students, pump priming, workshops with external stakeholders, and research visits to foster new collaborations and partnerships.

(iii) Cutting edge facilities. The successfully launched Centre for Genome-Enabled Biology and Medicine (CGEBM; **Salt**, Co-Director), will be further enhanced to bring together multidisciplinary teams interested in integrating genomics into their research, teaching and postgraduate training. This will provide BIS researchers with hands-on access to state of the art genomic technologies, including high throughput sequencing, with the delivery of learning activities and resources to enable BIS researchers to develop expertise in the application of these technologies.

Mechanisms to promote research excellence:
BIS working groups are convened to help facilitate the strategic aims or make recommendations on priority areas. BIS hosts core events, including workshops (e.g. on new approaches and techniques such as next generation sequencing) and research retreats (e.g. focused around imminent funding initiatives), and hosts symposia (formal and informal) and journal clubs/hot topics and seminar series, inviting internationally renowned scientists to Aberdeen to meet with researchers and discuss current and future collaborations. In 2012 BIS set up a horizon scanning group that feeds into SBS strategy to ensure we are strongly aligned with future directions in our research areas and for imminent funding calls, and to provide dialogue with funders and stakeholders on new scientific opportunities. The SBS operating plan is supported by dedicated central support for (i) development of funding applications (Research Financial Services), (ii) research contracts and technology transfer (Research and Innovation), including a business development team and specific support for international and European funding applications, (iii) support of small scale knowledge exchange activities (e.g. resourced through BBSRC £100k Sparking Impact award), and (iv) recruitment to academic and research positions, staffing strategy and staff development (Human Resources).

c. People

Staffing strategy and staff development:
Our staffing policy is centred on (i) appointments of scientists that are world leading in their fields, or more junior scientists on upward trajectories to be future leaders, to enhance our strengths in line with our research strategy and (ii) developing careers through mentoring and continuous professional development within (iii) a framework of opportunity and equality.

(i) ***Appointments of current and future leaders.*** We have successfully headhunted over the last three years and have made key appointments at professorial (**Salt**, **Hallett**), senior lecturer (**Teh**), lecturer (**Norton**) and independent fellow (**Gubry-Rangin**, **Hillier**) level; 3 to the Environmental Change group and 3 to the Plant-soil-microbe Interactions group. The strategy behind these appointments was to strengthen BIS in plant science and genomics, to bridge adaptation genetics and the soil environment, to fill a gap in soil physics, and to tackle issues of scaling from rhizosphere to landscape. These new appointments have been underpinned with appointment of 3 technical staff, a technologist and a bioinformatician, enhancing our analytical and technical capability, for example in establishment of the CGEBM (infrastructure investment £600k; operating £100k p.a.). Since 2008, BIS has celebrated 7 internal promotions to chair, 1 promotion to reader and 2 promotions to senior lecturer. Our current profile being returned to REF (22 staff, 20.4 FTE) is 12 professors, 1 reader, 5 senior lecturers, 1 lecturer and 3 independent fellows. Succession planning with targeted recruitment for Environmental Change and Plant-soil-microbe Interactions

demonstrates an enhanced delivery in our strategic priorities and research quality.

(ii) ***Developing careers.*** BIS works with the University to support the professional and career development of staff in accordance with the UK wide Concordat to support the Career Development of Researchers. A range of development opportunities are available to BIS staff, from specific development for PI training through to an award winning International Leadership Development programme for potential senior managers. All new academic staff prepare a three-year plan of objectives with an assigned mentor, which is reviewed annually and forms part of a 36 month probation. New appointees are given lighter teaching and administration loads in their first 2 years to allow them to (re-)establish their research groups. New staff are given dedicated research laboratory space, and are prioritised resource allocations and doctoral training PhD studentships. All researchers have annual appraisal and target-setting meetings, which strategically inform research, teaching and administration loads, and identify new opportunities for staff development, for which there is a University budget. A Framework of Academic Expectations was introduced in 2011 to enable staff to benchmark their performance. BIS adopts the procedure of internal peer review of grant applications at various stages prior to their final submission, and an internal review system for publications, with feedback from across the two BIS groups helping to increase submission to, and success rates with, the strongest journals.

The recruitment of independent research fellows (salary supported by their grant income) is a key part of our research strategy. Since 2008 we have supported two successful applications for free-standing fellowships in the areas of microbial ecology and climate modelling (**Gubry-Rangin**, and **Hillier**). We have also guided **Nicol**, **Baggs** and **Johnson** from NERC Advanced Fellowships through to lectureships/senior lectureships. Our vibrant research environment helps ensure these fellows can fast-track their careers, for example **Baggs** was promoted to the established Chair of Soil Science within 14 months of the end of her fellowship. We have an established framework of mentoring postdoctoral staff to develop their CVs and help them produce competitive independent fellowship applications. Early career researchers are represented on the SBS management groups and encouraged to take an active role in shaping the BIS research agenda and activity within our two groups, for example through membership of the SBS horizon scanning group.

(iii) ***Commitment to equality and diversity.*** The University applies this to all aspects of employment, including recruitment, promotion, development opportunities and disciplinary procedures. The University Court oversees the implementation of its Equality and Diversity Policy. BIS staff benefit from the University's Investors in People (IiP) status, recognizing and valuing the contribution of employees in accordance with the IiP Standard. The University received membership of Athena SWAN in 2011 (bronze award), in recognition of excellence in science, engineering and technology employment in higher education, and celebrating good employment practice for women. The College of Life Sciences and Medicine is in the process of applying for a bronze award followed by silver to SBS. BIS staff are members of the Esslemont Group which aims to raise awareness of gender issues and provide support for women in science.

Research Students:

BIS is successful in obtaining NERC DTG and BBSRC DTG/DTP studentships and externally competitive RCUK studentships; currently supporting 87 research students, with an additional 110 students graduated with PhDs since 2008. The research postgraduate students associated with BIS are an essential part of our research portfolio. This has been achieved through success in RCUK funding (Open calls, Responsive mode, Doctoral Training Grants, Doctoral Training Partnerships (DTP), Industrial CASE awards), Scottish Government organisations (e.g. Scottish Natural Heritage).and overseas funding (Walsh Fellowships, Marie Curie training awards (ITN, e.g. NORA, FP7), overseas governments, British Council). Our most notable studentship schemes are the BBSRC EASTBIO DTP, the most successful DTP in the UK in terms of studentships awarded, and the NERC EEcossE DTP application led by IBES. In addition we have a long history of joint studentships with our local research institutes (e.g. JHI and Scotland's Rural College). Within SFSAC (6 student starts p.a.) we host training networks between the Universities of Aberdeen and Dundee and the JHI in the areas of plant-soil interface, crop plants and food systems.

BIS staff foster strong links with commercial and other non-academic Institutions and companies. Since 2008 17 of our students have been funded by NERC/BBSRC/EPSRC Open or Industrial

CASE awards. These partnerships have led to the development of key technologies and advances in analytical capability. For example, the 'device for remediation and attenuation of multiple pollutants' (DRAM) was pioneered during a NERC Industrial CASE studentship, co-sponsored with the private company Enterpris, supervised by **Paton**. The innovation won a £400k award from the Scottish Government Proof of Concept Fund that took it from laboratory to near market. The commercial team, headed by **Paton**, was runner-up in the RCUK Business Competition, recipient of Scottish Enterprise Grampian Awards and shortlisted in the 2012 Rolex Awards. The technology is used for the remediation of contaminated waste and groundwater. The University holds the patent and this is licensed to EPONA Technologies Ltd, a University start-up company. BIS students are STEM ambassadors and have been involved in the Biotechnology Yes competition in 2009 (innovative application of biosurfactants for sustainable oil recovery), and in the Environment Yes competition 2010 (turning waste into biochar for use on farms).

Our critical mass in soils-related research means we address one of the areas LWEC has identified as central to their 'most wanted' postgraduate and professional skills needs in the environment sector. Our postgraduate body is enhanced through the hosting of NERC research experience placement students and student placements as part of the International Association for the Exchange of Students for Technical Experience (IAESTE, British Council). BIS encourages students to join external societies, present and discuss their research at annual conferences and early careers conferences, participate in IBES seminar series, student-led journal clubs, student led informal research discussions and seminars; all ideal opportunities for networking. There is an annual IBES postgraduate symposium at which students present talks and posters. BIS students successfully apply for funding for research travel and conference attendance.

Students join the Graduate School in the University's College of Life Sciences and Medicine, which is responsible for the training and mentoring of ~350 postgraduate research students. Development of research skills, transferable generic skills and discipline-specific techniques are defined in an individual student's Personal Development Plan. Mandatory training courses include an induction workshop on scientific conduct, research ethics and governance, project design, monitoring of progress, health and safety training, scientific writing, data handling, statistics, presentation skills, entrepreneurship and knowledge exchange. Generic skills courses are organised within the 'Skills for Research Excellence' programme. Students are closely mentored and their work is independently reviewed throughout their study period, through written reports, oral and poster presentations and vivas, helping ensure our students achieve their potential.

d. Income, infrastructure and facilities

The long term vitality and sustained research success of BIS staff has led to significant investment by the University since 2008 including 5 new academic posts, with associated infrastructure (£560k); equipment (£640k), studentships (£318k) and support staff (£88k p.a.), creating the world-leading research environment described here. BIS grant spend since 2008 totals £16.3M, supporting 101 postdoctoral research fellows and 11 technical staff over this period. Since 2008 BIS has hosted 5 NERC fellowships, and 5 Marie Curie fellowships. We are a recognised cluster of strength within a University in the top 10 in the UK with respect to funding from NERC and BBSRC. Our funding sources are diverse reflecting our ability to attract funds that cut across conventional discipline boundaries, for example, NERC, BBSRC, EPSRC, ESRC, EU, ERC, DFID, DEFRA, NSF, NIH, Scottish Government, Food Standards Agency, the Royal Society and the Royal Society of Edinburgh, in addition to an active funding stream from commercial organisations. Comprehensive plant growth facilities, a centralised analytical laboratory for soil, plant and water samples, and specialised analytical facilities are present on the Cruickshank site. This infrastructure is maintained and developed through direct cost recovery from external research funders, equipment bids, and the University Development Trust. In the previous assessment period the Cruickshank Building, which houses 16 of the researchers returned in this submission, was refurbished through SRIF at a cost of £2.3M. Since 2008 there has been a further £2.7M investment in infrastructure and resources for BIS research, most notably:

(i) The new Centre for Genome Enabled Biology and Medicine (£1.06M) which includes a dedicated Centre manager, two bioinformatician support staff, an equipment technician, one medium throughput sequencer (IlluminaMySeq), one high throughput sequencer (Ion Torrent Proton), laboratory refurbishment and four PhD studentships.

(ii) A new high performance computer cluster and associated support infrastructure (£600k). The cluster contains over 160 cores optimized for bioinformatic and statistical applications that significantly enhances the research computing capability of BIS, particularly in the areas of environmental modelling, and genomic and statistical genetic applications.

(iii) Establishment of new specialised laboratories: (a) soil physics laboratory with Instron mechanical test frame and digital direct shear (£100k), (b) high-throughput ICP-MS laboratory (£500k) for analyses of element traits in crops and model species.

(iv) Improvement of the controlled environment plant growth facilities (current investment £350k) for crop and non-crop temperate and tropical plants, including refurbishment of the research glasshouses and two new walk-in growth chambers.

(v) Joint investments with partners and access to their facilities. For example access to the centre for sustainable cropping and national soil archive in SFSAC, and to whole tree CO_2 chambers, CO_2 controlled glasshouses, free-air CO_2 enrichment experiment, eddy flux towers and next generation sequencing platforms with the University of Western Sydney.

e. **Collaboration and contribution to the discipline or research base**

Wider influence to discipline/research base: A key indicator of the wider influence of BIS is the range of key science advisory roles held by BIS staff. Selected examples are: **P Smith** has held a number of roles, most notably as member of DEFRA Science Advisory Council, an expert advisor to UK Government Committee on Climate Change, and as convening lead author on the IPCC 5th Assessment Report; **Strachan** has served as an external expert to the EU Food Safety Authority; **Woodin** has been a member of the UK Biodiversity Action Plan Steering Group and the UN ECE Review Group on Critical Loads for Nitrogen; **Woodward** is a member of the DEFRA task force on tree health and plant biosecurity, and a member of the ash dieback expert group (Government Office for Science); **Hallett** has served as policy advisor to the Scottish Government on the Scottish Soils Framework; **Paton** is a member of the Board of Scottish Environmental Technology Network; and **Prosser** is a member of the Society of Biology Education, Training and Policy Committee and is on the Scientific Advisory Board of DSMZ, Germany.

Fellowships and relevant awards: Since 2008 several BIS staff have received prestigious awards. For example, **Prosser** received an OBE (2013) for his internationally-renowned contribution to environmental sciences and was elected Fellow of the Society of Biology (FSB) in 2012. **P Smith** was elected a Fellow of the Royal Society of Edinburgh (FRSE) in 2009, FSB in 2009, and holds a Royal Society-Wolfson Research Merit Award (2008-2013). **Baggs** and **Johnson** were elected FSB in 2010 and 2013, respectively. In 2010 **Salt** was elected a Fellow of the Royal Society of Chemistry, in 2011 was elected a Fellow of the American Association for the Advancement of Science, and in 2013 elected a FSB. **Johnson** was Professeur Invité at L'Ecole Polytechnique Federale de Lausanne 2010-2011. **Paton** was appointed a Research Professor at the Institute of the Urban Environment, CAS, Xiamen 2009.

Participation in the peer review process: BIS staff have chaired and/or participated on grant committees. **Johnson**, **Nicol**, **Paton**, **Teh**, **Baggs** have served on the NERC College, with participation in several small grant, standard grant, fellowship, consortium grant and open CASE studentship committees as well as working groups, and **Baggs** is a member of the NERC Science and Innovation Strategy Board 2013-2016. **Prosser** has been a member of the CEH review panel. **Burslem** was on the NERC Human Modified Tropical Forests Steering Group, and **Baggs** and **Teh** have been members of the Life Science Mass Spectrometry Steering Committee. **Strachan** is a member of the ESRC Peer Review College, and has served on the MRC ESEI grant panel and the Food Standards Agency *E. coli* 0157 Panel. **Baggs** and **Price** have served on BBSRC committees (Committee B and BBSRC/DFID/B&M Gates International Development). BIS staff review grants for a wide group of funding bodies including (i) in the UK: RCUK, Royal Society, Royal Society of Edinburgh, British Ecological Society, Microsoft Research, Food Standards Agency, Defra, (ii) in Europe: ERC, in country research councils for the Netherlands, Switzerland, Germany, Poland, Bulgaria, Israel, Sweden, Czech Republic, Finland, Ireland, Norway (iii) in North America/Canada: NSF, USDA, Canada Foundation for Innovation, British Columbia Genomics Programme, NRCC Canada. (iv) Pacific: ARC.

Editors/editorial boards: Several staff have been editors of journals over the REF period

including: Annals of Applied Biology (**Price**), Ecology and Evolution (**Johnson**), FEMS Microbiology Letters, Plant and Soil (**Baggs**), Forest Pathology (**Woodward**), Frontiers in Terrestrial Microbiology (**Nicol**), FEMS Microbiology Ecology (**Prosser**, **Nicol**), Global Change Biology, Global Change Biology Bioenergy (**P Smith**), Journal of Hydrology and Hydromechanics (**Hallett**), ISME Journal (**Nicol**, **Prosser**), Microbial Ecology, Environmental Microbiology, and Applied and Environmental Microbiology (**Prosser**). BIS staff are involved in >45 editorial boards for a range of international journals, including 13 journals of impact factor 4 and above. All BIS staff have active roles in at least one editorial board. **Prosser** is Publications Manager for FEMS and a member of FEMS Executive Board. **Salt** is a member of the Faculty of 1000 editorial team.

Responsiveness to national/international priorities/initiatives: BIS have responded to international priorities, as exemplified in their lead of the SFSAC, and £10.8M funding in relation to global food security. BIS staff are part of SULSA, a pooling partnership between the Universities of Aberdeen, Dundee, Edinburgh, Glasgow, St Andrews and Strathclyde. In Aberdeen this allowed the development of systems biology research expertise that links with the Plant-soil-microbe Interactions group. We have also responded to UK wide initiatives to build critical mass and expertise, for example through our involvement in UKPopNet. Response to international initiatives in both Environmental Change and Plant-soil-microbe Interactions are exemplified in a recent award (£1.06M to BIS) in the NERC Human Modified Tropical Forests programme, where **Teh** leads a consortium across nine UK institutions and several international partner organisations in Malaysia, Japan, Brazil and the USA.

Effective academic collaboration: BIS has an outstanding track-record of international and national collaboration. Since 2008 successful collaboration (defined as joint peer-reviewed scientific papers, joint doctoral student supervision and joint active grants) by the 22 staff has involved 511 unique Institutions (comprising businesses, universities and government organisations) located in 65 countries, and 30% of current research student supervision involves collaboration with other organisations. This high level of collaboration is verified in the CWTS Leiden 2013 rankings which places Life and Earth Sciences at the University of Aberdeen as the top University in Scotland (8th in the UK) for international scientific collaboration.

Collaboration with industry: Examples of BIS spin-out companies include DRAM technology, EPONA Technologies Ltd (see section c), and the continued success of Remedios Ltd, which after 14 years has matured into a multi-ownership firm promoting innovative and sustainable environmental technologies internationally (Director; **Paton**). The University ranked (*PraxisUnico*) 6th in the UK for spin-out company formation in 2010-2012. **Strachan**'s human pathogen research involves close interaction with the Food Standards Agency, DEFRA and commercial companies and Prosser is a Director of NCIMB Ltd, an international Biological Resource Centre. Other industrial collaborations include those with instrument manufacturers, e.g. SerCon Ltd (**Baggs**).

Mechanisms to promote collaborations: Since 2008 BIS staff have organised and held key organisational roles for numerous international conferences. Selected examples include: two Rank Prize Fund conferences, Interdrought III and IV, Roots for the Future, iPlant, iHUB St Louis USA, Ecological and Evolutionary Genomics, FoodMicro 2008, Molecular Microbial Ecology Group, Rhizosphere, several COST Action meetings. We have several memoranda of understanding with key international institutions, including CAS, and joint PhD registration is encouraged with overseas Universities. Building national and international partnerships is central to our 5-year aims (section b). BIS enjoys particularly strong local links with the JHI with 27 co-supervised research students since 2008, joint staff appointments and secondments (**Taylor**, **P Smith**). Staff secondments to world-leading Institutions are particularly encouraged, for example Leverhulme Trust Research Fellowships for **Prosser** to UC Berkeley, Vienna and Oxford, and **Burslem** to Landcare Research, New Zealand in 2009. BIS funds are used to support exploratory visits for building partnerships. Visitors are encouraged; 36 visiting researchers have been attracted here since 2008, for periods of 3-18 months, funded by a variety of sources including national governments, Commonwealth Fellowships, the Royal Society, Marie Curie and ESF. Developing country partnerships (e.g. a recent memorandum of understanding with Abubakar Tafawa Balewa University, Nigeria, focused on plant-soil interactions) are facilitated through the University's Centre for Sustainable International Development (CSID), uniting economic, environment and social aspects to maximise the impact of our research.