Institution: University of Southampton

Unit of Assessment: 5 Biological Sciences

a. Overview (Cat A staff in bold throughout)

Since 2008, **Centre for Biological Sciences (CfBS)** staff have been proactive in the integration of biosciences research across the University resulting in a new interdisciplinary vision, the **Institute for Life Sciences (IfLS)** launched in 2010. Delivery of CfBS biosciences strategy has facilitated exceptional infrastructure for collaborative research supported by major University investment. An award-winning **Life Sciences Building** (**LSB**, £55M), located centrally in the University Highfield campus adjacent to other science and engineering buildings, was opened in summer 2010. LSB houses ~75% CfBS academics and researchers with selected IfLS collaborators from science, engineering and medical disciplines and a wealth of state-of-the-art facilities. To enhance the application of animal models in *in vivo* biomedical research, remaining CfBS staff relocated to **Southampton General Hospital (SGH)** campus in 2010 into refurbished laboratories and access to a modernised animal facility (£11M), enhancing collaboration with Medicine. To extend the biosciences agenda, CfBS moved into the **Faculty of Natural and Environmental Sciences (FNES)** in 2009 alongside Chemistry (adjacent in Highfield) and Ocean and Earth Science (**OES**, National Oceanography Centre, Dockside campus). CfBS comprises 41 academics (14 Professors; 27 Lecturers/Readers), 7 Senior/Independent Fellows, 38 postdocs and 81 PGR students (2013).

CfBS has three research themes spanning basic to translational science: **Molecular and Cellular Biosciences**, **Biomedical Sciences** and **Environmental Bioscience**, each supported by investment in new academic staff (17 since 2008 including new CfBS Head and Director of IfLS). Cumulative income in research grants starting from 2008 is £31.20M from 119 grants with £17.60M (58 grants) being collaborative with non-CfBS staff at Southampton University. CfBS driving of integrative biosciences is further evidenced by our leadership in **University Strategic Research Groups (USRGs)** that bridge conventional discipline boundaries to address priority societal issues and grand challenges. Of 13 USRGs, CfBS staff include overall Director of Multidisciplinary Research (**Poppy**), Chair of 3 (**O'Connor**, *Neurosciences;* **Taylor**, *Energy*; **Smith**, *IfLS Director*) and Vice-Chair in *Sustainability Science* (**Eigenbrod**).

b. Research strategy

CfBS research strategy since 2008 has been (i) to develop the integrated biosciences vision, from genes and molecules through to organisms, populations and communities; and (ii) to ensure its three themes comprise staff and facilities to sustain and expand interdisciplinary research, achieved through relocation to the LSB and SGH and direct integration with IfLS. Most (37, 92%) CfBS staff are also members of the IfLS (Director: **Smith**) which has 254 academic members across all 8 University Faculties. The LSB provides a vibrant interdisciplinary core community with exceptional facilities and with CfBS staff in the majority. Similarly, at SGH, CfBS staff share common laboratory and animal facilities with Medicine, facilitating collaboration.

Molecular and Cellular Biosciences: The aim is to interpret basic properties and genetic coding of macromolecules and to apply this understanding to human physiology and disease. The 10 staff have established advanced facilities in LSB and include 6 new appointments since 2008 (**Coldwell** 2008; **Tews** 2010; **Smith** 2011; **Ewing**, **Gibson**, **Siddle** 2013). They provide expertise in structural biology, nucleic acids, gene regulation, mRNA translation, proteomics, protein interactions, intracellular signalling and the molecular basis of disease. There are extensive interactions with researchers in CfBS (e.g. Microbial Biofilms; Neuroscience), Medicine (e.g. Cancer Sciences (Elliott); Human Development and Health (Byrne)) and Chemistry (Brown, Gale) and with the Diamond Light Source (**Tews**). Notable funding includes Wellcome Trust Programme (£1.33M) and 5 BBSRC (~£1.9M) awards plus substantial industrial funding (AstraZeneca, Janssen) for **Proud** all as PI on structure and regulation of translation factors; plus BBSRC sLoLa support for **Fox** (Co-I with Brown, Chemistry and Oxford; £1.83M) on synthetic gene construction for *in vivo* applications.

(i) Protein science and structural biology*:* Structural biologists closely align with Chemistry (including EPSRC National X-ray Crystallography Service) and Medicine to establish powerful research facilities in LSB comprising solid-state and solution NMR, crystallography, and proteomics (see **d**). Novel structure/function relationships have been revealed for a range of proteins important in macromolecular synthesis and transport in pro- and eukaryotes (**Tews**). Lipid interactions with

potassium channels have provided mechanistic insight into channel opening and activity (**East**).

***(ii) Cellular Regulation**:* DNA triplex technology has been exploited and novel oligonucleotides developed for precise targeting of DNA sequences and to create nanostructures for controlling gene expression (**Fox**). Novel insights into proteome diversity have been gained by identifying alternative initiation sites for translation of specific mRNAs (**Coldwell**). At the genetic level, multimetric approaches to determine the location of causal genetic polymorphisms underlying disease have been explored in genome-wide data, showing increased precision using a combination of single SNP and composite likelihood techniques (**Gibson**). At the cellular level, new regulatory mechanisms controlling synthesis of proteins and ribosomes downstream of mTORC1 and MAP kinase have been identified. For example, eEF2K is critical for cell protection during nutrient or oxygen starvation, providing a new target for cancer therapy and with applicability to cardiac hypertrophy, cardiovascular disease and neurological disorders (**Proud**). Down-regulation of MHC molecules using epigenetic mechanisms has been identified in the contagious cancer, Devil Facial Tumour Disease, explaining how transmission occurs between individuals without eliciting an immune response and providing new targets for vaccine production (**Siddle).** Advanced cell imaging technologies have been used to show anti-apoptotic Bcl-xL enhances the efficiency of energy metabolism within neurons and is a positive regulator of synapse formation (**Smith**).

***(iii) Post-genomic technologies**:* Bioinformatics capacity has been extended by development of programmes for identifying short linear motifs involved in protein:protein interactions (e.g. SLiMFinder) and tools for the identification of novel translation start sites in mammalian mRNAs (**Edwards**, **Coldwell**). Methods have been developed for large-scale proteomic analysis of non-model organisms (BUDAPEST, FIESTA) in collaboration with the Centre for Proteomics Research and staff from OES (**Edwards**). Next generation sequencing (**NGS**) approaches (RNAseq, Metagenomics and SuperSAGE) are being applied to study molecular responses to environmental stresses in plants and marine algae (**Edwards** with **Taylor**, **Terry** and National Oceanography Centre; **NOC**). New computational models for analysing and predicting protein-protein interactions from proteomic data have identified key regulatory proteins involved in DNA methylation and gene expression programmes in mouse embryonic and epiblast stem cells (**Ewing**).

Biomedical Sciences: This theme is focused in ***Neuroscience*** and ***Developmental Biology*** and has strong links with Medicine, Chemistry and Engineering. It contributes to University and national (RCUK, Wellcome Trust) priority areas on causes of neurodegenerative and metabolic diseases within an ageing population, spanning basic mechanisms to clinical and commercial research.

(i) Neuroscience: The group of 9 staff includes 4 new appointments (**Teeling** 2008; **Deinhardt**, **Vargas-Caballero**, **Gomez-Nicola** 2013) and all are members of the Southampton Neuroscience Group (www.southampton.ac.uk/song **SoNG**), a University-wide network providing links with clinical neuroscience, psychology, healthcare professionals and engineering. SoNG thus offers a broad and interactive context for translational benefit underpinned by basic and clinical research. CfBS ***Neuroscience*** contributes basic research into neurodegeneration, neuroinflammation and synaptic signalling and plasticity. These activities support applied research in Alzheimer's disease (**AD**), stroke, traumatic brain injury and alcohol addiction with relevance to the grand challenge of lifelong health and well-being. The group utilise and refine invertebrate (*C. elegans*, *Drosophila*) and mammalian models, incorporating molecular, genetic, cellular, systems, mathematical and behavioural neuroscience. Invertebrate pest problems and hence food security are addressed with projects defining the actions of novel, neuroactive antiparasitics used in animal health, tropical medicine and crop protection. Key funding since 2008 includes BBSRC support for plant parasitic nematode neurobiology (£0.38M; **Holden-Dye**, **O'Connor**); Wellcome Trust funding for systemic brain infection (£0.35M; **Teeling**, **Perry**) plus major EPSRC support to **Chad** with Optoelectronics (£1.16M) for NANOSCOPE - looking inside a living cell with nanoscale resolution. Commercial benefits from our ***Neuroscience*** research are strong (UoA 05, ICS 05 and 07). Gene candidates and molecular pathways in alcohol-induced behavioural changes and parasitic nematode drug sensitivity have been identified (**Holden-Dye**, **O'Connor**). Mechanisms of synaptic degeneration (**O'Connor**, **Perry**) and systemic inflammation have been revealed in AD progression (**Perry**, with Medicine) while a *Drosophila* model has identified the role of protein abnormalities in AD and Huntingdon's disease **(Mudher**). Amyloid-tau protein interactions have been shown in AD, representing a promising strategy for treatment (**Vargas-Caballero**). Nerve growth factor signalling mechanisms influence neuronal remodelling in development and adult disease (**Deinhardt**).

Effects of bacterial infection and immune complex formation on neuroinflammation and adaptive behaviours have been revealed (**Teeling**). Modulating the activity of IL-15 has been shown to regulate microglial activation in the brain and the proinflammatory state (**Perry**, **Gomez-Nicola**). Advances in super-oscillatory high resolution microscopy have been made and novel CNS tissue engineering analogue developed for *in vitro* use (**Chad, O'Connor**).

***(ii) Developmental Biology*:** This group of 5 staff includes 2 new appointments (**Clarkin**, 2011; **Jones**, 2013) investigating basic processes in reproductive and developmental biology plus mechanisms underlying the Developmental Origins of Health and Disease (DOHaD; University-wide programme). Extensive links occur with Medicine (Hanson, Torrens, Godfrey, Burdge, Macklon). Major grants since 2008 include mechanisms of peri-conceptional induction of adult disease (**Fleming** as PI with CfBS/Medicine CIs, 2 BBSRC for £1.2M and EU-FP7 awards). Food industry supports research (£7.9M) on protective food supplements against adverse epigenetic programming of disease (**Lillycrop** with Medicine). Identification of epigenetic markers of disease (**Lillycrop**) and resulting translational opportunities have been supported from NIHR (£9.6M) with Godfrey (Medicine PI) for a Biomedical Research Centre in Nutrition, Diet and Lifestyle. Genetic control mechanisms of meiotic arrest and resumption and chromosome segregation in mouse oocytes have been identified using mainly transgenic models which impact on causes of human chromosome aneuploidies such as Down's Syndrome (**Jones**). New mouse models of adult offspring cardiovascular, metabolic and immune system disease have been developed from altered peri-conceptional environment mediated through poor maternal diet and sickness (**Fleming**). Maternal diet has been shown to programme epigenetic and phenotypic changes in F1 to F3 generations and epigenetic marks in humans detected at birth with potential as predictive markers of adult disease (**Lillycrop**). Mouse transgenic models have identified transglutaminase function and disease association (**Smyth**). *In vitro* and *in vivo* models for bone development and disease have been devised and used for analysis of vascular-bone cell communication (**Clarkin**).

Environmental Biosciences: The interaction of prokaryotes, plants and animals with the environment is investigated at molecular, cellular, whole organism, population and landscape scales. Combined skills in molecular biology, genetics, evolution and ecology provide capacity to address current and future global problems of sustainable use of natural resources, food and energy security, adaptation to a changing environment and species conservation. The 11 staff including 3 new appointments (**Eigenbrod** 2010; **Chapman** 2012; **Ezard** 2013) are active in USRGs (*Sustainability Science, Energy, Complexity Science* and *Web Science)* combining ecological skills with mathematical modelling, spatial mapping, remote sensing and computing.

***(i) Microbial Biofilms*:** CfBS staff are core to the IfLS Biofilms & Microbial Communities, a vibrant cross-Faculty grouping, the largest such team in the UK. The CfBS group focuses on the genetics, molecular ecology, evolution and development of biofilms and their environmental and clinical impact. Major projects include development of antimicrobial properties of copper touch surfaces to reduce healthcare associated infection, leading to hospital trials worldwide and major impact of this research in the public domain (**Keevil**: PI, Copper Development Association, £0.97M). Copper alloy surfaces for enhanced anti-microbial protection have been developed with rapid degradation of microbial DNA/RNA and prevention of horizontal gene transfer on dry touch surfaces, a cause of multi-drug resistance of important pathogens (**Keevil**). Nitric oxide signalling has been shown to control biofilm formation and dispersal with biofilms undergoing genetic diversification through defects in DNA mismatch repair in a process similar to growing tumours (**Webb** with Medicine).
(ii) Plant Sciences: The environmental effects on plant function are addressed, including the use of plants for renewable energy, crop science responses to abiotic and biotic stresses and strategies to improve crop nutrition. Major awards include identification of the molecular genetic basis of high yield in bioenergy poplar (**Taylor**, PI, EUFP7 ENERGYPOPLAR and EUROCHAR; £0.46M) and improved photosynthetic performance for marine algal biofuel production (**Terry**, CI, Carbon Trust £0.61M with OES and NOC). Communication mechanisms between nucleus and chloroplasts have been revealed that control chloroplast biogenesis (**Terry**). Mineral-transport proteins have been identified in crops and their role in micronutrient deficiency and cellular processing determined (**Williams**). X-ray tomographic microscopy has been developed for 3D visualisation and quantification of phosphate uptake by live plant root hairs in soil (**Marchant** with Engineering). The genetic basis of anti-oxidant status in lettuce has been determined and SNP markers developed for breeding of nutritionally enhanced crops (**Taylor** with Sainsbury's).

(iii) Ecology and Environment: Adaptations to environmental change are addressed including organismal responses to stress factors and human responses to shifting ecosystem services. Expertise in mathematical modelling, NGS in un-sequenced non-model species and spatial ecology is applied to plant, invertebrate, amphibian and mammalian models. Notable awards include developing drought-tolerant crops using NGS and molecular breeding of poplar (**Taylor**, PI, EU-WATBIO €9M, £0.61M to Southampton); quantifying greenhouse gas balances in bioenergy crops and using trees as biodiversity drivers (**Taylor** EU-EVOLTREE, £0.37M; ETI-ELUM, £0.41M); interdisciplinary studies on managing ecosystem services for food security at forest-agricultural interface (**Poppy**, PI and **Eigenbrod** CI, NERC ESPA £0.83M; with Engineering and Social Sciences); and development of conservation corridors (**Doncaster** PI, Darwin Initiative and Fellowship; UoA 05 – ICS 06). Raised atmospheric CO_2 has been shown to delay leaf-fall in temperate forest ecosystems associated with transcriptome remodelling (**Taylor**). Interactions of climate change with ecology have been shown to drive macro-evolutionary dynamics differentially affecting speciation and extinction (**Ezard**; with Faculty of 1000 “must-read” publication). Current ecosystem services have been quantified and modelled for future land-use and urbanisation (**Eigenbrod**). A regulon underpinning floral evolution and ecological trait transfer between species has been revealed plus genes involved in adaptation to altitude (**Chapman**). Plant nutrient supply has been shown to alter chemical defences against herbivorous insects and competition between insects (**Poppy**). Techniques have been developed for distinguishing niche from neutral processes in population ecology, and parasitism from altruism in evolutionary biology (**Doncaster**).

Coordination and development of CfBS research strategy: CfBS research policy is devised by the ***Research Strategy Group*** (**RSG**) chaired by Director of Research with members representing the research themes, the IfLS, the Faculty (Associate Dean Research, ADR), Enterprise, ECRs, PGRs, Finance and the University Research and Innovation Services (**RIS**, see below). RSG formulates the CfBS Research Strategy Plan, identifies new research directions and appointments, interdisciplinary collaborations, informs on funding opportunities and implements research governance and ethical policy. RSG also manages research facilities day-to-day, identifies equipment needs and devises policy and support for grant application processes including peer review prior to submission. Research strategy is developed with a rolling plan plus annual academic Away Days to review and refresh medium- and long-term goals. RSG reports to the CfBS ***Policy and Resources Committee*** (**PRC**) chaired by the Head of CfBS with representation across research, education and enterprise sectors. PRC manages the entire business of CfBS including implementation of research policy, overseeing the use, management and financing of research infrastructure (technical, facilities), and reviewing grant applications, awards and funding with Finance. CfBS research strategy is directed to Faculty level and into the Faculty Strategic Plan through formal links between CfBS (Head; Director of Research), IfLS (Director), Faculty (Dean; ADR) and other agencies (e.g., USRGs). An **External Advisory Board,** comprising leaders in scientific companies, charities, government agencies and research institutes, provides advice and strategic guidance to CfBS across its research, enterprise and outreach activities to enhance impact on industry, government and society and promote training, skills and employability of students. **Interdisciplinary research** is supported through USRGs (see **a.**), IfLS matching funding for interdisciplinary PGRs and infrastructure, and an annual cross-faculty Multi-User Large Scale Equipment Round (**MULSER**; providing 50% funds with matching external award). CfBS research is stimulated through external and internal seminar programmes within themes and across CfBS, journal clubs, and full day symposia run by CfBS, IfLS, SoNG, USRGs and related groups across the University. Research grant application support is provided both at early planning (e.g. theme forums for advice on strategy, design and collaborators offered especially to ECRs) and at advanced pre-submission stage (internal peer review panels). All grant applications are read and signed-off by experienced colleagues. RIS, the technology transfer arm of the University, links academic research to industry, develops and maintains contacts with external partners and RCUK, helps maximise commercial and societal impact of research outputs, and assists in identifying funding sources. The University European Office assists in EU research call intelligence, writing, financing, proposal submission and post-award financial and contractual issues.

Five year forward planning: Given CfBS growing income streams and anticipated retirements, we plan to expand the academic staff base with 10 new appointments to support our CfBS Research Strategy Plan. Three have recently been made in Bioinformatics and Biochemistry/Molecular/Cell Biology with two more in basic Biosciences in post by early 2014. Future priorities include:

Quantitative Evolutionary Biology; Structural Biology; Metabolomics; Soil and Sediment Meta-genomics; Developmental Epigenetics; Biogeochemical Cycles. With existing expertise, these appointments will support our drive for tackling priority global challenges through RCUK, EU (FP8 Horizon 2020), charities and other sources. Individual theme plans include:

Molecular and Cellular Biosciences will use systems-based applications to aid design of small molecules to interfere with intracellular signalling networks and as research tools or potential therapeutic agents; enhance structure/function capability for integral membrane proteins which are strategic pharmaceutical targets for tackling conditions such as multi-drug resistance in hospital-acquired infections, These areas fit our current expertise; require interdisciplinary skills from IfLS, Chemistry and Medicine; and align with RCUK ageing research and lifelong health priorities.

Biomedical Sciences will extend links with Medicine, Psychology and Engineering plus industrial partners to develop and investigate new integrative approaches in the key areas of neurodegeneration; synaptic plasticity and signal processing; dietary, health and IVF-related developmental programming; identification of epigenetic biomarkers in metabolic disease. These aims fit University and national priorities especially dealing with ageing populations.

Environmental Biosciences will expand research on translational benefits of biofilms in infection and contamination control; plant adaptations to stress; the food-energy-water nexus; eco-evolutionary dynamics; ecosystem services and poverty alleviation. Plans are ongoing for isotopic and elemental analysis of biogeochemical cycles (with OES) and for NGS facilities to analyse metagenomes of soils and sediments and environmental genomics in non-sequenced organisms.

PGR Student Recruitment*:* Continue to expand PGR student numbers through i) CfBS PGRs, ii) PGR Steering Group review and promotion of external PGR recruitment opportunities, iii) PGR School engagement with enterprise/outreach activity to promote links with external funding partners, iv) promote CfBS competition in University PGR schemes (eg, IfLS, Vice-Chancellor's).

c. People, including:

i. Staffing strategy and staff development

Career development: New academic appointments match priorities within the CfBS Research Strategy Plan. Staff career development is supported through line management, PPDR and senior staff mentoring to identify specific goals and training needs, aided by University Strategy commitment to "developing our people" to full potential. The central Professional Development Unit (**PDU**) coordinates support and training for all staff, ECRs and PGRs with wide-ranging courses and online resources. A research sabbatical is available for all academics every 4 years. PDU support for ECR career progression was lead through a University Advisory Group chaired by **Perry** (CfBS) to ensure compliance with the Concordat to Support the Career Development of Researchers, mediated through Faculty ECR Working Groups (FNES: Chair, **Holden-Dye**, CfBS). ECR staff in CfBS have mentorship to support integration and progression with PDU providing a 2-day workshop and courses on generic skills (e.g. grant writing, IT, research management). CfBS has an active **Research Fellows** Society to support networking and career progression. Formal annual appraisal and career support for all Fellows is practised plus opportunities for Fellows to lecture on UG modules within their specialty and engage in PGR supervision and training.

Equality and diversity**:** The University Equality Plan is fully supported by CfBS in provision of improved cultural, ethnic and religious awareness in an internationalised campus. Female career development is a priority: women in CfBS have a high profile comprising two of four senior managers (Directors of Research and Enterprise). All female academics have been retained since 2008. CfBS has a wide-ranging Action Plan to ensure women are adequately represented across all activities including commitment to the university-wide Athena Swan Action Plan. An application is pending for a CfBS Athena Swan Bronze award. Gender balance within our committee structures is advocated at all levels and seminars and committee meetings occur within the core day to allow for family commitments. Full entitlement to appropriate work/life balance, provision of maternity and paternity leave, and opportunities for job-sharing are encouraged at all levels. PDU support for female researchers is also available in courses (e.g. Managing your Academic Career for Women), workshops and information. The AAAS-*Science* booklet (2009) 'Young Women in Science' includes a 2-page spread on CfBS UNESCO-Loréal Fellowship (Guichón, 2004-5).

ii. Research students

Organisation and funding: PGR students join the CfBS Graduate School headed by a senior

academic (**Webb**), managed by a Steering Group with PGR representation, integrated within the Faculty structure for governance. The Graduate School oversees and administers recruitment and admissions, with overseas promotion by the International Office. Since 2008, 81 PGRs have been enrolled by CfBS (16.2/year average) funded through RCUK (30.5; BBSRC 18.5, MRC 6, NERC 3, EPSRC 2; ESRC 1; 10.5 are CASE), Gerald Kerkut Trust (10.5), University/Faculty/CfBS (10), charities (3), private (7.5), commercial (4), EU (4), ERC (1), overseas (9), Government (1.5). Technology applications by BBSRC CASE PGRs include microbial pathogen decontamination in the food industry (with Vitacress) and molecular genetic screens of *C. elegans* for anthelmintics (with Bayer). Over 22% of CfBS PGRs are co-supervised with non-CfBS staff, a proportion increasing in line with our biosciences vision. A BBSRC DTA with Medicine has supported 14 PGRs over 3 years (9 to CfBS) and a new DTP in Food Security (lead Reading) begun in 2013. Annual IfLS PGRs are awarded for interdisciplinary projects involving supervisors from distinct fields. CfBS-supported PGRs (current 4) fund staff with external collaborators. CfBS are core contributors to the University successful NERC DTP application with 9 external partners awarding 15 PGRs/year for 5 years. PhD recruitment is increasing, with 29 funded PGRs in 2013/14 (~double previous years) due to CfBS PGRs and success in University competitions (e.g. IfLS).

Training: PGR induction and training includes personal development, generic skills (e.g. bioethics, safety, presentations), specific bioscience technologies (aligned with RCUK Vitae Researcher Development Framework), networking, team building and ample outreach activities in schools, research and enterprise centres (e.g. Southampton's award winning Science and Engineering Day; CfBS Open and Public Engagement Days; RCUK Public Engagement with Research Catalysts award 2013-16; Wellcome Trust Society award in Authentic Biology 2012-15). The Researcher Development & Graduate Centre (**RDGC**) and Career Destination Unit enhance PGR culture centrally in transferable skills (e.g. CV production, job interviews, outreach, IP, entrepreneurship) and participation in Biotechnology Young Entrepreneurs Scheme, SET for Britain and Royal Society Summer Exhibition. RDGC offers online research skills training to complement face-to-face activities. PGRs contribute to research group meetings, thematic seminars, journal clubs, and oral/poster presentations at the Annual PGR Conference and external conferences. A new (2013) vibrant CfBS Postgraduate Society enhances student participation in research events and organisation of the PGR conference. The Graduate School oversees PGR supervision and monitoring. Each PGR has a supervisory team with at least two academics (plus industrial supervisor for CASE/industrial PGRs). New supervisors complete the University PhD supervisors' course and are teamed with experienced staff. PGR performance is assessed by literature review (5 months); MPhil/PhD Transfer (Year 1, mini-thesis, viva); Full Report (15-22 months; mini-thesis; viva). Feedback occurs at all stages, enhanced by online PGR Tracker for progression and milestones. The Destinations of Leavers from Higher Education (DLHE) Survey 2011/12 showed 89% CfBS PGRs in full time professional work and 11% in full time study. CfBS PGRs gave positive approval (84%) of the training in the PG Experience Survey (PRES; 2013).

d. Income, infrastructure and facilities

Income*:* During the assessment period CfBS staff have held 186 grants worth £48.54M to Southampton (including 119 starting from 2008, worth £31.20M), either as PI (144 awards, bringing £27.02M to CfBS) or as CI (80, £6.10M). The total income to CfBS of £33.12M from these grants (including £19.98M in grants starting from 2008) is a substantial increase over the last RAE which reported a total income of £15.8M from 2001 to 2008. The current reporting period also saw a rise in award success following the migration of CfBS to LSB and SGH completed 30/6/2010. Income to CfBS was £7.80M from 49 awards starting in the 2½-year period 1/1/2008-30/6/2010, and £12.18M from 95 awards starting in the following 3¼-year period 1/7/2010-31/9/2013. This trend continues with £2.4M already awarded in new grants by October 2013. As indicated below, we have achieved significant awards for collaborative projects with non-CfBS staff in all three research themes, providing evidence for the success of the integrated biosciences concept.

Molecular and Cellular Biosciences: Staff have held 41 grants worth £12.84M during the assessment period (29 starting during the period, worth £9.02M), either as PI (33 awards, bringing £6.87M to CfBS) or as CI (15, £1.46M). The total income to CfBS of £8.33M (of which £6.46M from 34 PI or CI awards starting during the period) came from RCUK (awards worth £4.59M), charities (£3.09M), industry (£0.40M), EU (£0.18M), and other (£0.05M) sources. A significant number of grants (13, worth £6.01M) included non-CfBS awardees, in Chemistry (11 awards, worth £3.42M),

Medicine (6, £0.37M), Engineering (3, £0.41M), and Electronics & Computer Science (£0.04M).

Biomedical Sciences: Staff have held 73 grants worth £18.89M during the assessment period (50 starting during the period, worth £13.71M), either as PI (48 awards, bringing £7.61M to CfBS) or as CI (49, £3.18M). The total income to CfBS of £10.79M (of which £6.14M from 64 PI or CI awards starting during the period) came from RCUK (awards worth £5.86M), charities (£3.05M), EU (£1.07M), industry (£0.75M), and other (£0.05M) sources. A significant number of grants (32, worth £12.11M) included non-CfBS awardees, in Medicine (58 awards, worth £5.15M), Chemistry (3, £1.27M), Electronics & Computer Science (9, £1.25M), and other departments (£0.34M).

Environmental Biosciences: Staff have held 72 grants worth £16.82M during the assessment period (40 starting during the period, worth £8.47M), either as PI (63 awards, bringing £12.54M to CfBS) or as CI (16, £1.47M). The total income to CfBS of £14.01M (of which £7.38M from 46 PI or CI awards starting during the period) came from RCUK (awards worth £4.30M), EU (£3.70M), government (£2.78M), industry (£2.30M), charities (£0.28M), and other (£0.64M) sources. A significant number of grants (18, worth £5.27M) included non-CfBS awardees, in Electronics & Computing Science (3 awards, worth £1.00M), Medicine (11, £0.95M), Ocean & Earth Science (4, £0.60M), Civil Engineering (6, £0.31M), Social Sciences (2, £0.31M), Geography (6, £0.14M), Institute of Sound & Vibration Science (1, £0.10M) and other departments (£0.26M).

Infrastructure and Facilities: Major improvements in research facilities occurred during CfBS relocation to LSB and SGH. LSB includes a wing for advanced facilities with experimental officers and management structure for operational and financial sustainability and user groups to promote collaborations and drive new equipment grant proposals (e.g. 3 University MULSER awards in microscopy; proteomics and NMR with 50% external funding since 2008). Facilities include:

(i) *Biophysical Facility*: Instruments laboratory for analytical and physical measurements of biomolecules comprising GC, GC-MS and HPLC linked to tandem quadrupole electrospray or orthogonal acceleration TOF-MS. Spectroscopic studies are supported by a circular dichroism spectropolarimeter, a single photon-counting spectrofluorimeter, dual wavelength spectrophotometers, a stopped-flow rapid reaction analyser, and an isothermal calorimeter.

(ii) *X-ray crystallography*: New facility following Chemistry award of National Crystallography Service (2010) and internal funding provides a crystallisation pipeline and diffraction facilities for macromolecular structure determination. Includes Rigaku Alchemist screen maker, Grypton Nanodrop, crystallisation plate imagers and plate hotel.

(iii) *Centre for Proteomic Research* *(CPR,* with Medicine*):* CPR has increased its capacity and capability for sample preparation/mass spectrometry and bioinformatics computing. Instruments include gel and liquid handling robots, a high-throughput MALDI-Tof and two Q-Tof (Global Ultima and Micro) instruments with 2D nanoUPLC systems and a triple quadrupole tandem MS (Waters, Xevo TQ) for targeted analyses. New CPR instrumentation (£1.4M award) includes high-resolution mass spectrometers (Waters G2-S with ESI and MALDI ionization sources and nanoacquity UPLC system; Thermo Orbitrap Elite and Dionex 2D-UPLC system).

(iv) *Imaging and Microscopy Centre* *(IMC)*: IMC expanded in move to LSB and comprises light, confocal and multiphoton fluorescence microscopy plus preparation and containment level 2 areas. Equipment includes a Leica TCS SP2 FCS multiphoton microscope; a Leica SP8 confocal with hybrid detectors; a Zeiss LSM 510 Meta UV confocal microscope; a PerkinELMER spinning disk confocal microscope; four wide field fluorescence microscopes; a new infrared scanner (LiCOR Odyssey); and separate image analysis workstations running Volocity software. Facilities permit flexible combination of confocal and wide field fluorescence microscopy with electrophysiology. Microscope PCs are networked and data backed up by OMERO client-server platform.

(v) *Biological NMR*: The expanded NMR facility shared with Chemistry (£1.2M University award) hosts a solution NMR at 600 MHz with cryoprobe for analysis of soluble biomolecules, and 400 and 600 MHz solid-state NMR instruments (Wellcome Trust support) for analysis of solid biological samples and materials science including weak samples and membrane proteins.

(vi) *Tissue culture*: This facility in LSB is equipped with incubators and suitable for culture of stem cells and primary tissue in separate wings, the latter adjacent to the animal holding facility.

(vii) *Transgenic (TG) Facility*: This re-located to refurbished SGH labs and provides expertise in TG mouse production via pronuclear DNA and blastocyst ES cell approaches plus sperm and embryo cryopreservation, re-derivation and recovery of cryopreserved TG lines. Facilities include a

Zeiss Axiovert 200M inverted microscope with Eppendorf micromanipulators and Femto-Jet microinjector; sterile surgery area for implantation of embryos, and controlled rate freezer. The facility resources animal provision to LSB holding area for Highfield CfBS and IfLS researchers.

(viii) *Invertebrate Facility*: This FERA-licensed facility (University award, £800K) comprises insect (locust; *Drosophila*) and nematode (*C. elegans*; parasitic) suites plus 9 controlled-environment rooms (**CERs**) for organism culture and bioassays and a preparation space. One CER houses several wind tunnels. Data are logged automatically and can be accessed remotely.
(ix) *Plant Growth Facility*: This comprises 9 CERs (2 FERA compliant) specialised for plant-insect interaction studies and glasshouse (300 m^2) located on the LSB roof (£1.8M University investment with £800K from largest ever University donation for plant growth research). The CERs provide light, temperature and humidity, all individually computer-controlled with permanent environmental monitoring and remote access. The glasshouse (CambridgeHOK) comprises 8 separate growing zones with independent constant environmental monitoring and a potting area with autoclave.

Other facilities supported by CfBS: Category 3 Suite, Lipidomics, Biomedical Research Facility (Medicine); Supercomputing (Computational Modelling Group); Mass Spectrometry (Chemistry).

e. Collaboration or contribution to the discipline or research base

Indicators of wider influence and contributions to the research base (54% of staff)
External assessment of institutes: IWW Institut für Wasser at Mulheim, CEN Technical Committee at Brussels, British Standards Institute EH/5 Wastes and CH/216 Antimicrobial Surfaces, US Dept Agriculture in Washington (**Keevil**); Imperial College, Swedish Agricultural Univ, Lancaster Environment Centre (lead reviewer) (**Poppy**); Scientific Advisory Board of BNA, Roslin Instit, MS Centre at VUMC Amsterdam, DEFRA TSE Research Advisory Group (**Perry**); Academy of Finland, Strategic Centres for Science Technology and Innovation (**Taylor**); others by **East**, **Ewing**, **Fleming**, **Fox**, **Holden-Dye**, **Jones**, **O'Connor**, **Proud**, **Smith**.

Other contributions: Early Career Council Member and Trustee of British Ecological Society, (**Ezard**); National Chairman of Christians in Science (**Fox**); panel of Excellence in Research Australia (**Jones**); deputy chair of Nuffield Council on Bioethics, member of Dementia Research Champion Group, DEFRA TSE Research Advisory Group (**Perry**); member REF2014 sub-panel 6, Trustee Marwell Zoo (**Poppy**); Chair and Trustee of Vitacress Conservation Trust (**Taylor**); Deputy Chair of Plant Section Committee of Society for Experimental Biology (**Terry**); Policy Committee member for Society for General Microbiology (**Webb**). Other examples of wider influence: **Doncaster**: 130,000 pageloads in REF period of website for Doncaster & Davey (2007) textbook. Submitted staff delivered 174 invited lectures, of which 20 were keynote.

Participation in the peer-review process (51% of staff – selection below)
Chair of grant-awarding body: MRC Neuroscience and Mental Health Board (**Perry**). *Membership of grant-awarding bodies*: NERC (**Doncaster**); NIH, National Institute of Allergies and Infectious Diseases (**Ewing**); British Ecological Society (**Ezard**); Wellbeing of Women Research Advisory Committee, Royal Society International Grant committee, (**Fleming**); Research Council of Norway (**Holden-Dye**); Australian Research Council's College of Experts Biological Sciences and Biotechnology (**Jones**); European Science Foundation, Ireland Higher Education Authority (**Keevil**); Alzheimer Society grant and Drug Development (**Mudher**); Norwegian Research Council Panel Chair, Royal Society Fellowship Panel (**O'Connor**); BBSRC panel, NERC ESPA Grant Evaluation Committee (**Poppy**); British Heart Foundation (**Proud**); MBL Fellowship Committee, NIH, National Institute for Biomedical Imaging and Bioengineering (**Smith**); FP7 EC Research Assessment Panel, UKERC Research Committee, European Science Foundation Panel Assessor, Singapore A* Science Programme Panel, French Agence Nationale de la Recherche panel, BIOADAPT panel (**Taylor**); BBSRC (**Terry**); Science Foundation of Ireland, NIH Review Panel, National Institute of Allergy and Infectious Diseases (**Webb**).

Fellowships, awards, and visiting professorships (40% of staff)
Fellowships include UCITE Glennan (**Ewing**); NERC Advanced Fellowship (**Ezard**); BBSRC David Phillips (**Webb**); American Academy of Microbiology Royal Society of Medicine (**Keevil**); Academy of Medical Sciences (**Perry**); Society of Biology (**Holden-Dye**, **Keevil**, **Poppy**, **Taylor**).

Awards: Charles Downie Award, Micropalaeontological Society (**Ezard**), Marshall Medal, Society for Reproduction and Fertility, RCOG Fellow *ad eundem* (**Fleming**); Royal Society Wolfson Research Merit Award (**Perry, Proud**); David Blow Prize, British Crystallographic Association

(**Tews**). *Visiting professorships* include Chinese Academy of Sciences (**Jones**); Edinburgh Univ (**Perry**); Imperial College, Oregon State Univ (**Poppy**); China Ocean Univ, Xi'an Jiaotong Liverpool Univ (**Proud**); Edinburgh Univ (**Smith**); Imperial College, UKM Kuala Lumpur (**Taylor**).

Journal editorships (51% of staff)
Staff are on editorial boards of 36 journals. Highlights include Editors-in-Chief of *Reproduction* (**Fleming**), *Nucleic Acids Research* (**Fox**), *Invertebrate Neuroscience* (**Holden-Dye**).

Effective academic collaboration (100% of staff)
CfBS staff published 659 ISI-indexed papers since 2008 (notably **Perry** 74, **Proud** 41, **Keevil** 40), with 3148 co-authors from 990 organisations outside CfBS in 63 countries, citing 527 funding sources (BBSRC on 106, EU 71, NERC 47, Wellcome 45, MRC 35, NIH 29). Papers generated WoS h-index 36 from 7235 citations, including 56 reviews with h-index 22 from 1748 citations (highest 356: **Perry** 2009 in Ann Rev Immunol). These metrics represent an increase on the previous REF-equivalent period 2002-2007, which had 6041 citations by end 2007 from a similar number of ISI-listed papers (666) though with fewer co-authors (1655) and fewer reviews (44). In the current period PGR students published with 86% of submitted staff. PGRs went on to postdoc posts for **Doncaster**, **Marchant**, **Mudher**, **O'Connor**, **Perry**, **Taylor**, **Terry**.

Collaborative interactions with industry or government (40% of staff, selection below)
Industry: CAPSANT (**Chad**, **O'Connor**); Copper Development Assoc, Mantis, Steris, Veolia Water, Wessex Water (**Keevil**); Bayer Animal Health consultant (**Holden-Dye**); Abbott Nutrition, Danone, Nestlé (**Lillycrop**); Davunetide, MRCT (**Mudher**); GSK (**Perry, Teeling**); Agrisense, Exosect, Syngenta, Vale S.A., Sainsbury's (**Poppy**); Shamrock Seeds, Eon (**Taylor**); Lundbeck (**Teeling**); INO Therapeutics, Pfizer (**Webb**); Microsoft Research (**Werner**); Sainsbury's, Marks & Spencer, Vitacress Salads (**Keevil**, **Taylor**, **Webb**).

Government: MOD Independent Scientific and Technical Advice Register, DEFRA Drinking Water Inspectorate, DoH Decontamination Working Group (**Keevil**); UK Foreign Office delegation to Delhi, and to Beijing with RCUK and Royal Society on Global Food Security (**Poppy**); DEFRA, Natural England, SNH and CCW (**Eigenbrod**); UK OST, ETI Strategic Advisory Group, Bioenergy, Energy delegation Far East; DECC Bioenergy Strategy (**Taylor**); Parliamentary Scientific Committee on Antibiotics at House of Commons 2013 (**Webb**).

Responsiveness to national and international priorities and initiatives (43% of staff)
Conference organisation: includes Biochemical Society Focused Meetings 2010-13 **(O'Connor, Coldwell, Proud)**; Translation UK 2012 (**Coldwell, Proud**); Local Organising Committee INTECOL 2013 (**Ezard**); Royal Society of Chemistry E. coli and Coliforms 2011, RSC Water Contamination Emergencies 2012 (**Keevil**); Biochemical Society Biology and Pathology of Tau (**Mudher**); BNA National Committee (**O'Connor**); New Phytologist Symposium Bioenergy Trees 2011, stakeholder groups for chalk stream management 2008-12 (**Taylor**); Wessex Immunology Group 2012 (**Teeling**); International Symposium Plant Photobiology 2013 (**Terry**); International Biodeterioration and Biodegradation Society 2012, International Biofilms IV and V 2012-13 (**Webb**); South West Structural Biology Consortium 2012 (**Tews**).

Chairs of agenda setting meetings include NIH Research Policy-forming workshops on Preconception Care and DOHaD (**Fleming**); Royal Society Discussion Meeting on Food and Ecological Security in London, Kavli International Centre Workshop, WUN Adapting to Climate Change Meeting in Washington DC (**Poppy**).

Working parties: Nuffield Council on Bioethics, on Dementia, on Reaching Out to Young People (**Perry**), Organiser, EC and US Agriculture and Energy Departments, Sustainable Biofuels and Life Cycle Analysis, DECC Energy Minister and Chief Scientist Bioenergy Supply group(**Taylor**).

Mechanisms to promote collaborative research
57% submitting staff received funding by IfLS and/or USRGs. 6/13 new staff since 2008 won grants (17 in total). Growth of collaborative activities underpinned by EPSRC BTG grants, cross-faculty studentships with Complex Systems Simulation DTA, targeted University studentships (12 to CfBS), and structured forums (annual meeting based, USRG, seminar programs, SoNG, RIS, Funding Alerts). Staff involved in mentoring women and early-career scientists (**Holden-Dye, Poppy**), public engagement (**Mudher**, **Poppy, Smyth**, **O'Connor**, **Teeling**) and school liaison activities (**Holden-Dye**, **Mudher, Poppy**, **Teeling**).