Institution: Imperial College London

Unit of Assessment: 5 Biological Sciences

a. Overview

The Department of Life Sciences (DoLS) at Imperial College London is one of the largest groups of biological scientists in Europe, with 89.5 FTE academic staff, 183 research staff, 178 PhD students, 190 Masters and 816 UG students. DoLS is located on 2 campuses at South Kensington and Silwood Park, and sits in the Faculty of Natural Sciences (FoNS), which was established in 2005 to exploit the interdisciplinary nature of research in the Physical and Biological Sciences. Activities are supported by a wide variety of research councils, charities and industrial bodies, with external funding over the REF period of £146M. Research activity is organised into themes, namely **Anaesthesia, Sleep and Pain**; **Bacterial Pathogenesis**; **Cell and Developmental Biology**; **Ecosystems and the Environment**; **Evolutionary Biology**; **Glycobiology**; **Infection and Immunity**; **Integrative Systems Biology**; **Membrane Biology**; **Molecular Mechanisms of Disease**; **Molecular Plant and Microbial Systems**; **Synthetic Biology**. In addition to these core themes, DoLS staff are integrated into a number of multidisciplinary research centres. This submission comprises staff in DoLS, plus *Fisher & Korchev* from the Faculty of Medicine (FoM), whose activities are closely aligned with the Unit of Assessment. We are returning 97.1% of our academic staff and independent research fellows, in keeping with our philosophy that the maximum possible number should be research active.

b. Research strategy

Mechanisms and practices for developing, promoting and disseminating research, and sustaining and developing an active and vital research culture: We aim to conduct research at the highest international level in an intellectually challenging and inspiring environment, and maximise its impact. To support this strategy, the DoLS Management Group determines academic appointments, policies for operational procedures and use of resources. Recruitment of staff and students is detailed in section c. The Research Strategy Committee advises on research opportunities and development of infrastructure to support research, outlined in section d. Academic staff and research fellows are associated with one or more of the research themes. Each theme is assigned a budget which funds away days, workshops, and postdoc and PhD symposia. The monthly departmental seminar series hosts national and international invited speakers. Additional seminar series are organised through the Centre for Structural Biology, the MRC Centre for Molecular Bacteriology and Infection, the Institute of Systems and Synthetic Biology, Silwood Park and other cross-departmental groupings.

Information on funding opportunities is disseminated and bids organised through research themes and centres. FoNS has a range of internal Strategic Research Funding schemes: **Collaboration Kick-start funding** enables multidisciplinary teams to develop large bids for external funding by supporting feasibility/exploratory studies (5 awards totalling £80K to DoLS); **Institutional Support Funding** provides institutional commitment and support for external funding applications (4 awards, £80K); upgrading/sharing of **Research Equipment** (5 awards, £65K). Several schemes are funded through the Wellcome Trust Institutional Strategic Support Fund (ISSF): **Networks of Excellence** provides matched funding to support strategic high quality research, scientific exchange and translation (4 cross-Faculty awards with DoLS totalling £408K); **ISSF Sabbaticals** support short visits to promote interdisciplinary, inter-institutional collaboration (2 awards, £20K); **Value in People** provides bridging support up to £30K for staff between grants and fellowships (16 awards, £310K). DoLS staff have also benefitted from support schemes such as **Creativity Labs**, an internal strategic research fund to establish cross-Department collaborative networks which lead to submission of funding proposals, **Shaping Capability: Bridging the gaps**, which provides funding for people-based activities centred on novel approaches to cross-disciplinary interaction and collaboration, as well as internally-managed schemes with external funding such as **EPSRC Kick-Start** and **EPSRC Strategic Funding**, **BBSRC Sparking Impact** and **NERC Impact Accelerator**.

Overview of research position relative to RAE 2008: In 2008 the Department was comprised of 3 Divisions (Ecology & Evolution, Cell & Molecular Biology, and Molecular Biosciences). Each Division had a separate administrative structure, PhD programme and research governance, the latter organised into 7 constituent sections. In 2010 we restructured 2 of these sections; Cell Biology & Functional Genomics, and Plant & Microbial Sciences, creating a new section of

Integrative Cell Biology. In 2011, staff in Biophysics were re-located with colleagues in Life Sciences, consolidating research activities at South Kensington. In 2013 we removed divisional and sectional structures to foster interdisciplinary research, provide a unified administrative framework and enhance collaboration across the Department. Since RAE 2008 we have built on our 5-year forward plan which was informed by the major themes of Environment, Heath and Energy. An investment programme has allowed us to make new academic appointments in strategic areas, refocusing our research strengths and addressing national and international priorities. Major areas of investment include experimental systems and synthetic biology, the latter via establishment of the Centre for Synthetic Biology & Innovation **(CSynBI**) and the Innovation and Knowledge Centre **(SynbiCITE),** the MRC Centre for Molecular Bacteriology and Infection **(CMBI),** a new research grouping to address developmental biology using model organisms **(Cell & Developmental Biology),** expansion of interests in industrial biotechnology and bioenergy, including the Artificial Leaf Project, and investment in the Membrane Protein Lab (**MPL**) at Diamond Light Source. The NERC Centre for Population Biology was replaced by a major initiative: the **Grand Challenges in Ecosystems and the Environment (GCEE)**, which strives to ensure the future wellbeing of humanity and ecological systems in a world of global change. Over the REF period, 42 staff have left (12 retirements, 28 moves and 2 deaths), and we have made 47 new appointments, including 15 new research fellows.

Research groupings and strategic aims: Within DoLS, staff are organised into 12 research themes, with grant income over the period, strategic aims, and selected major achievements outlined below. Interdisciplinary research is encouraged and promoted via an extensive range of cross-Faculty Centres: Centre for Integrative Systems Biology and Bioinformatics (CISBIO), Centre for Structural Biology, Cross Faculty NMR Centre, Electron Microscopy Centre, Glycobiology Training, Research and Infrastructure Centre (glycoTRIC), MRC Centre for Molecular Bacteriology and Infection, Institute of Systems and Synthetic Biology, Neurotechnology Initiative, Grand Challenges in Ecosystems and the Environment.

Anaesthesia, Sleep and Pain (£5.3M): Mechanisms underlying how sleep is initiated and maintained, the loss of consciousness induced by general anaesthetics, and the molecular basis of neuropathic pain. Major achievements include determination of the molecular site of action of the intravenous anaesthetic propofol (*Franks*), how central synapses are modified during sleep (*Gilestro*), and how subtypes of GABA neurons contribute to memory formation (*Wisden*).

Bacterial Pathogenesis (£14.1M): Molecular mechanisms underlying bacterial disease, virulence and antibiotic resistance. In 2012, we secured £3.3M funding from the MRC to establish the Centre for Molecular Bacteriology and Infection **(CMBI)**, a joint venture with FoM. Achievements over the period include showing how *P. aeruginosa* sensor kinases regulate development of acute or chronic infection (*Filloux*), how *E. coli* block apoptosis (*Frankel*), and how *C. difficile* regulate antigenic variation in cell wall proteins (*Fairweather*).

Cell and Developmental Biology (£2.5M): A new core group studying plant developmental biology has been created by recruitment of *Sena* and *Song* to join *Turnbull*. Molecular imaging continues to be a major strategic focus: *Korchev* has developed new tools for live cell imaging, and *Lo Celso* has pioneered *in vivo* tracking of haematopoietic stem cells in mouse models.

Ecosystems and the Environment (£11.8M): Addresses global issues of environmental changes and their effect on complex ecosystems. Recent appointments include *Prentice* (AXA Chair in Biosphere and Climate Impacts), *Woodward, Knight, Raymond, Suttle* and *Banks-Leite* (ecosystems and conservation biology). Highlights include the Stability of Altered Forest Ecosystems project, which examines how logging and fragmentation modify tropical rainforests and affect biodiversity (*Ewers*). An additional 11 academics and 2 fellows have been recruited to tackle the issues addressed by the **GCEE** initiative, detailed below.

Evolutionary Biology (£21.1M): How organisms have evolved to become adapted to their biotic and physical environments, global patterns of biodiversity, and microbial evolution. Highlights include OneZoom, a fractal explorer for the tree of life (*Rosindell*), new mechanisms for evolution of species on oceanic islands (*Savolainen*), new links between bacterial diversity and ecosystem function (*Bell*), interplay between biotic and abiotic drivers of macroevolution (*Purvis*), and determination of requirements for malaria control using genetically modified mosquitoes (*Burt*), funded by Gates Grand Challenges in Global Health.

Glycobiology (£4.6M): Strategic aims include understanding the role of glycans in host-

pathogen/commensal interactions, receptors and cell-cell communication. We host the Glycotechnology Core for the international Consortium for Functional Glycomics, which supports the research of over 600 investigators worldwide. Highlights include determination of the major carbohydrate ligand for human sperm-egg binding (*Dell*), and a mechanism for LSECtin binding to Ebola virus surface glycoprotein (*Drickamer*).

Infection and Immunity (£28.4M): Addresses immune system functionality and immunity to a wide range of pathogens in vertebrates and invertebrates. Highlights include the identification of E4BP4/NFIL3, a transcription factor defining the NK cell lineage (*Brady*), identification of a novel nanotube-mediated mechanism of inter-leukocyte communication (*Davis*) and, in collaboration with the Physics department, the first use of optical projection topography on live organisms (*Dallman*). *Fisher* highlighted the emergence of fungal pathogens as a driver of extinction in global amphibian populations, and *Baum* (Wellcome NIA and succession for *Sinden*) made major contributions to malarial parasite invasion of erythrocytes. *Lawniczak* (MRC CDF) showed advanced speciation in mosquito vectors, and *Windbichler* (ERC starting grant) designed a synthetic homing endonuclease-based gene drive system for mosquito control.

Integrative Systems Biology (£10.4M): Members develop and apply mathematical, statistical and computational approaches to biology. Highlights include web-based protein structure prediction using the Phyre server (*Sternberg*), Bayesian design of synthetic biological systems (*Stumpf*), and modeling of chemotactic gradient sensing by single cells (*Endres*, ERC starting grant). These theoretical biologists are complemented by new experimentalists *Isalan,* who has made major advances in rewiring bacterial gene networks and engineering zinc finger proteins for gene therapy of Huntington's disease, and *Sena*, studying organ regeneration in *Arabidopsis*.

Membrane Biology (£12.6M): Strategic aims include determination of the structure and function of integral membrane proteins, targets for the majority of available drugs. *Iwata* (BBSRC Diamond Professorial Fellow) and colleagues have determined the structures of numerous complex membrane proteins, whereas *Matthews* (Wellcome SIA) utilises NMR to elucidate the structural basis of cellular recognition, invasion and biofilm formation by pathogens.

Molecular Mechanisms of Disease (£11.3M): Focuses on important cellular processes such as stress, protein synthesis and turnover, and DNA damage responses. *Guerra* (Wellcome CDF) generated mutants in activating receptors to elucidate the role of NK cells in cancer development. Other highlights include *Zhang*'s (Wellcome SIA) work on DNA binding of gene regulators and regulation of ATPase activity in AAA+ proteins, and the structural basis of sequence-specific collagen recognition by the extracellular matrix protein SPARC by *Hohenester* (Wellcome SRF and SIA), now a full time member of academic staff.

Molecular Plant and Microbial Systems (£11.5M): Aims include understanding whole organism physiology, responses to infection, and biochemistry/biophysics of photosynthesis, enhanced by 4 new academic appointments: *Rutherford*, Chair in Biochemistry of Solar Energy, working on photosystem II; *Murray*, protein engineering to mimic the catalytic activity of PS II; *Jones*, engineering microorganisms for development of renewable fuels; *Bozkurt*, specializing in fungal effectors who complements *Spanu* and creates a strong group in plant infection.

Synthetic Biology (£12.3M): Aims to develop tools for synthetic biology, using these to generate innovative biological applications for research, healthcare and industry. The Centre for Synthetic Biology & Innovation (CSynBI) is a flagship research centre directed by *Freemont* (Life Sciences) and *Kitney* (Bioengineering). *Heap* developed breakthrough genetic technologies for the anaerobic bacterial genus *Clostridium*, engineering these industrially and medically important organisms, whereas *Buck* designed modular and orthogonal genetic logic gates in *E. coli* in order to build robust biologically-based digital devices to customise cell signaling.

Responsiveness to national and international priorities and initiatives, and multi-disciplinary developments: Recent investment has allowed us to reposition research in the context of national and international priorities, with expansion of activities in synthetic biology, industrial biotechnology, bacterial pathogenesis, molecular plant and microbial systems, and stem cell/developmental biology contributing to BBSRC strategic research priorities *Agriculture and food security*, *Industrial biotechnology and bioenergy,* and *Bioscience for health*, and appointments in systems biology addressing *Systems approaches* and *Technology development for the biosciences* and *Exploiting new ways of working.* Staff in the Membrane Biology, Molecular Mechanisms of Disease, Anaesthesia, Sleep and Pain, Infection and Immunity and

Glycobiology themes work on infectious and non-infectious disease and elucidate mechanisms of drug action, relevant to MRC, BBSRC and CRUK objectives, whereas staff in Ecosystems and the Environment, and Evolutionary Biology themes address numerous NERC strategic priorities. **CSynBI** was established in 2010 in partnership with the BIOS Centre at King's College London through a £4.5M EPSRC Science and Innovation award to build new activity in areas of national strategic importance. The Centre is a collaboration between DoLS and the Department of Bioengineering, and is part of the Institute for Systems and Synthetic Biology. The aim of the Centre is to establish a robust engineering framework for the design and optimisation of new synthetic biology parts, devices and systems, and to integrate this research with emerging ethical legal and societal issues. This was followed in 2013 by the award of £10M from EPSRC, BBSRC and the TSB to establish an **Innovation and Knowledge Centre in Synthetic Biology.** The centre (**SynbiCITE**) aims to boost the UK's ability to translate synthetic biology into application, and provide a bridge between academia and industry. This national resource will involve 17 other universities and academic institutions across the UK and 13 industrial partners, including the research arms of Microsoft, Shell and GSK. Synthetic Biology has been flagged by David Willetts as one of the Eight Great Technologies which the UK needs to prioritise, and establishing the IKC was one of the recommendations of the 2012 UK Roadmap for Synthetic Biology. *Iwata* was awarded the first BBSRC Diamond Professorial Fellowship to establish the **Membrane Protein Laboratory (MPL)** at Harwell adjacent to the Diamond Synchrotron Light Source in 2010. **MPL** was created as a research and training user facility for determination of membrane protein structures by X-ray crystallography open to scientists worldwide, and DoLS supports this resource with an additional 2 scientific staff and 1 administrator. **CMBI** was established with £3.3M from the MRC and support from Imperial College. DoLS supported the initiative with £940K investment (2 new lectureships, 2 PhD studentships and £250K in start-up funds and infrastructure costs). Application for the centre was invited by the MRC in response to the serious rise in bacterial infections and the alarming increase in drug resistance, and CMBI collaborates with Imperial College-associated hospitals and industry to tackle these issues. DoLS invested £500K in the **Artificial Leaf Project** (2011-14), aimed at developing catalytic systems which harness solar energy to turn carbon dioxide and water into chemical fuels, vital for the development of carbon neutral and renewable fuels and a major international strategic priority. The potential to store solar energy in chemical bonds addresses another of the Eight Great Technologies prioritized by the government, and this project is integrated into the multi-disciplinary **Energy Futures Lab** at Imperial. The **GCEE** is the latest major initiative to address high level Cross-Council priorities *Living with environmental change*, and *Lifelong health and well-being; global food security*. It was launched in 2013 with 11 appointments and £1.5M committed expenditure on infrastructure and facilities. Core staff include 6 senior international joint appointees (*Halpern, Jetz, Jones, Possingham, Tylianakis, Rahbek*), who will spend at least 20% of their time at Imperial, linking activities of the GCEE with ongoing research in their home institutions. The initiative also involves the Faculties of Medicine and Engineering, the Grantham Institute for Climate Change, and the Centre for Environmental Policy.

Objectives and activities in research over the next five years: The major areas identified as strategic priorities over the next 5 years are outlined below:

- Develop the **GCEE** initiative, using expertise provided by new appointments including *Araújo* (integrative biogeography), *Lloyd* (global ecosystems function), *Holt* (macro-ecology & biogeography), *Gill* (behavioural ecology & pollination), *Hodgson* (biological anthropology & human evolution), *Pawar* (systems biology, ecological theory) and *Windram* (synthetic biology). This initiative is closely linked to evolutionary biology, which has been strengthened by recruitment of *Bell, Brazeau, Rosindell* & *Friman*.
- Work with other Departments across the College to create the Imperial College **Institute for the Environment**, and develop it as an initiative of international excellence.
- Genetic modification of insects to control vector-borne diseases. This initiative has been enhanced by appointment of 2 research fellows, *Windbichler* & *Lawniczak*, with guaranteed lectureships, providing succession in insect genomics with the departure of *Kafatos*.
- Develop a multi-disciplinary College-wide approach to the growing problem of antibiotic resistance, and specifically expand interactions with the Department of Chemistry to this end.
- Utilise our broad expertise in structural biology to further research on disease biology,

metabolic processes and synthetic biology. *De Simone, Bubeck, Beeby, Drew* (RS URF), *Hare* (MRC CDF) and *Low* (Wellcome CDF), are new appointments in this area.
- Develop research in Bioenergy, working with the Energy Futures Lab. This will be driven by new appointments *Rutherford* (succession to *Barber*), *Jones* and *Murray*, together with *Nixon*.
- Use the **CSynBI** to develop new synthetic biology activities in areas of national strategic importance. *Isalan, Jones, Murray* and *Heap* are new appointments who use synthetic biology approaches in their research programmes.
- Expand our interests in epigenetics, stem cell renewal, differentiation and developmental patterning in plant and animal model organisms. *Southall, Barkoulas* and *Song* are newly appointed staff who will drive developments in this field.
- Continue to invest in imaging to underpin many of our activities in collaboration with staff in Photonics (e.g. *French*) and Medicine (e.g. *Korchev*). Expand interests in cryo-electron tomography (*Beeby* brings new expertise to this area) and single molecule imaging.
- Incorporate systems approaches to many of the research programmes described above. This is already being addressed by the recent appointments of *Isalan, Sena, Gilestro* and *Wisden*.

c. People, including:

i. Staffing strategy and staff development

Staffing strategy in relation to research strategy and physical infrastructure: Our fundamental strategy is to hire outstanding individuals, place them in coherent research groups, and provide wide-ranging support to allow them to build strong research programmes. This vision includes maintaining a supportive culture in which early career researchers can maximise their potential and develop their careers. Staffing is intimately linked to the research strategy, with consideration of teaching requirements at UG and PG levels. Decisions are made by the Departmental Management Group, with advice from the Research Strategy Committee, and we carefully monitor funding opportunities and performance in each research theme in order to maintain critical mass in a sustainable staff structure. New academic appointments have been made in strategic areas. Our recent focus has been in hiring young staff (28 Lecturers over the period), with the exception of areas in need of leadership; e.g. *Isalan* (Experimental Systems Biology); *Rutherford* (Artificial Leaf); *Prentice & Araújo* (GCEE), resulting in a vibrant and strong Department. Space is not a major constraint, but we have sought to improve interactions between research groups. Thus, where possible, members of a research theme are grouped together on a single floor, with some inter-disciplinary activities such as **CSynBI** housed in space shared with Bioengineering, and cross-Faculty initiatives such as **CMBI** co-located with Medicine. Staff in the **Ecosystems and the Environment** and **Evolutionary Biology** themes are located primarily at Silwood Park, with facilities for large-scale ecological experiments.

Recruitment: Permanent academic appointments are made to those believed to have the ability to rise to the level of Professor. To ensure a rigorous recruitment process, this involves the widest possible advertisement of positions, targeted searches, a broad shortlisting panel, an open seminar to the Department, and an interview panel with academic staff including at least 1 woman, a College Consul and, for Professorial and Reader appointments, at least 2 external experts. In order to facilitate recruitment and retention of staff, the College has implemented housing support schemes: affordable housing for those earning under £60k, shared equity, and a housing deposit scheme in the form of an unsecured loan. DoLS has taken advantage of these schemes to recruit 4 key academic staff over the REF period.

Development and support for Early Career Researchers (ECRs)

Academic Staff: New lecturers are appointed for a 3-year probationary period in which they are assigned an academic adviser, a senior member of staff who provides guidance on preparation of research grant applications, management of research projects, and good teaching practice. The academic adviser meets regularly with the new lecturer and prepares a report for their line manager and HoD at the end of each term. Progress is assessed at a Mid-Probation Review in the 5th term of service, and a Final Review in the penultimate (9th) term. Review panels consist of the HoD, the line manager, the academic adviser, and additional relevant academic staff. New lecturers are assigned no substantive administrative duties and a reduced teaching load during their first 3 years of appointment to enable them to secure funding and build a solid research programme. The teaching load is not prescribed but is generally in the range of 8

lectures plus associated tutorials in the first year, incrementing annually. FoNS has established a Learning and Teaching Development Programme for new lecturers which is normally completed within 1-2 years of appointment. The Research Office organises internal grant review and mock interviews for applicants for ERC starting grants and Wellcome NIAs, and the high success rate of recent applications for these (*van Thor, Endres, Ewers, Lo Celso, Bell, Windbichler, Baum*) attests to the effectiveness of this support. In 2012 FoNS set up the specific scheme **Upgrading the Small Equipment Base for Early Career Researchers**, through which ECRs can apply for up to £10K to purchase small equipment (5 awards to DoLS thus far).

Research Fellows: The Junior Research Fellowship (JRF) scheme, funded by the College since 2009, provides 3 years salary and £15K p/a research support for the brightest and best ECRs from around the world. The scheme is run annually, aimed at researchers with <4 years postdoc experience, providing an important transition to independence. Since inception, 7 awards have been made to DoLS. In addition, over the period DoLS has hosted 26 independent researchers with fellowships secured in competition from a range of external sources, providing extensive support for applications (section e). Research Fellows are granted the status and benefits of other academic staff in terms of space, access to facilities, Masters and PhD students, in order to develop their research fully. We actively support career progression: of the 26 individuals who took up fellowships in the period, 13 were appointed to permanent academic posts in DoLS (*Christophides, Ewers, Beis, Cota Segura, van Thor, Bell, Orme, Polizzi, Gilestro, Murray, Hohenester, Rudenko, Banks-Leite*), with a further 6 positions guaranteed at the end of the fellowship (*Artavanis-Tsakonas, Guerra, Rosindell, Pinney, Lawniczak, Windbichler*).

Postdoctoral Research Associates: DoLS has a large cohort of postdoctoral researchers (currently 140), whose contracts specify 10 days personal transferable skills training per year. The College's Postdoctoral Development Centre (PDC) provides a tailored programme of courses inside and outside academia. These include a personal development course for women, a bespoke scheme for JRFs, career development training and one-to-one coaching. The PDC received a "HR Excellence in Research" badge from the EC in recognition of its alignment with the *European Charter for Researchers and Code of Conduct for their Recruitment* and the *Concordat*; it was also shortlisted for "Outstanding Support for Early Career Researchers" at the 2010 Times Higher Education Awards. Mock interview panels have proven particularly useful to junior researchers preparing for Fellowship or Lectureship interviews. Our RAs and ECRs have made full use of the opportunities provided: 212 attending its courses, 94 receiving one-to-one coaching sessions and 24 taking mock interviews over the REF period. DoLS has a very active Postdoc Committee which organises seminars and symposia, funded by the Department, and has set up an informal mentoring/buddy system.

Development and support for established academic staff: We place considerable emphasis on reducing the administrative burden on academic staff to liberate time for research. An extensive review of undergraduate (UG) teaching in 2011 streamlined courses for more efficient and effective use of time, and a dedicated UG Liaison Officer has been appointed to act as a first point of contact for students. New core research support administrators have been hired to assist with costings and preparation of research grant applications, and a network of line managers established. These senior academics have a responsibility for 5 members of staff on average, and meet academic staff for an annual Personal Review and Development Plan (PRDP) meeting to discuss teaching, research (including impact), internal contribution and career development. These facilitate constructive dialogue regarding promotions, teaching, implementation of strategies and communication of funding opportunities. PRDPs are conducted at all levels; i.e. for probationary and confirmed academic staff, research fellows and PDRAs.

The departmental **Promotions panel** chaired by the HoD consists of line managers for promotion to Senior Lecturer/Reader, and all Professorial staff for promotion to Professor. Candidates for promotion to Reader and Professor are interviewed by a panel chaired by the Faculty Dean. Nurturing and enabling the career progression of our younger staff is key to maintaining our research strength, and all staff submit their CVs in our annual promotions exercise. Nomination is by line managers, with a parallel route for self-nomination. A total of 30 promotions were made in the period, 7 to Senior Lecturer, 16 to Reader and 7 to Professor. FoNS has a wide range of internal Strategic Research Funding schemes as outlined in section b. In addition, we frequently support staff in applications for Royal Society Wolfson Research

Merit Awards, and there have been 10 recipients of these over the REF period. We select staff, encourage them to apply, and peer review applications. We also encourage staff to apply for more senior fellowships, as outlined in section e, with support (review of applications and mock interviews) provided through the Research Office. **Sabbatical leave** is encouraged and awarded up to a maximum of three terms after six years of service, contingent upon a coherent plan for research and staff development. Over the REF period, 9 staff have taken sabbatical leave; 6 in this submission i.e. *Christophides, Fairweather, Williams, Ewers, Frankel* and *Barraclough*.

Support for equalities and diversity: The College provides a dedicated Equalities Unit and support network, including Imperial as One (ethnic background), Imperial 600 (LGBT), and Disability Staff and Student Forums. Our leadership programme for black and minority ethnic staff, iLead, has been so successful that Stellar HE, a development programme for leaders across 10 HEIs, was modeled on it, and we also run a leadership programme for disabled staff. DoLS formed an Academic Opportunities Committee (AOC) in 2008 which includes male and female representatives at all career stages, and received an Athena SWAN Bronze Award in 2011. Much of the AOC's 12-point action plan has been implemented, including increased female representation on the DoLS Management Group. The Elsie Widdowson Fellowship Award is a highly successful College scheme which allows female academics returning from maternity/adoption leave to concentrate fully on research. This award provides central funding for 50% of salary costs for 12 months, and is used to relieve the academic of any teaching or administrative duties. There have been 8 recipients of these awards in DoLS (*Zhang, Byrne, Desikan, Bubeck, Brown, Hall, Power, Butcher*). The College has also expanded the South Kensington childcare facilities to 140 places, with priority given to academic women.

ii. Research students

Recruitment and selection: To attract the best-qualified candidates, we advertise on the College website, findaPhD.com and in select publications, with access to admissions material on the institutional website. Postgraduate (PG) Open Days at South Kensington and Silwood Park provide a main focus for recruitment. Prospective students visit the Department and discuss their research interests with staff members. In the last 5 years DoLS received an average of 190 applications p/a, approximately 50% from overseas, and recruited 58 students p/a on average, recruited on the basis of their academic performance and research potential. All PhD students must have at least a good 2.1 BSc and normally also hold a Masters degree. Shortlisting involves prospective supervisors and members of the departmental Postgraduate Education Committee. Interviewing is carried out by at least 2 members of academic staff who make recommendations to the Director of Postgraduate Studies (DPS) in writing. Our MRes programmes are also a route for PhD entry, with 17% of students entering PhD studies in 2012 on 1+3 doctoral training programmes. DoLS has received several BBSRC Doctoral Training Grants (DTG), the latest awarded in 2009 at £2.6M, and *Buck* (DoLS) is the grant holder for the current BBSRC Institutional Doctoral Training Partnership (DTP), awarded in 2011. DoLS is a major partner in the NERC Institutional DTP "Science and Solutions for a Changing Planet", announced in November 2013. This was the highest ranked submission, receiving 15 studentships p/a, of which 4-5 p/a will come to DoLS based on NERC grant income. In addition, we have been continuously funded by the Wellcome Trust for a 4 year PhD programme in Infection jointly with FoM, £3.7M for 2009-2013 and just renewed at £4.1M for 2014-2018. We receive 1+3 MRC funded studentships from the Institutional MRC DTG, and additional studentships are provided by the Faculty Schrödinger Scholarship Scheme, and joint funding from Imperial College and the Chinese Scholarship Council (CSC), the National University of Singapore, and Hong Kong University. In total, DoLS admitted 288 PhD students between January 2008 and January 2013, funded by over 20 different sources. Research Councils provided support for 125 awards as follows: BBSRC (81) NERC (29), MRC (9), and EPSRC (6). Other studentships were provided by the Wellcome Trust (12), other UK Charities (6), other UK scholarships (11), overseas government scholarships (35), overseas non-government studentships (18), Imperial College studentships (11), Departmental bursaries (16), and 54 were self-funded.

CASE awards and application of technology generated by research students: DoLS received 47 CASE awards supported by 27 funding organisations. Examples of technologies

generated by research students include a new drug screening platform used by big pharma (*Nonoo et al*. 2012 *ChemMedChem* 7, 2082-2086), an NMR software assignment aid used in the Collaborative Computing Project for NMR (*Marchant et al*. 2008 Biomol NMR Assignments 2, 119-121), and software for predicting protein structure such as Poing, developed by *Jefferys* and incorporated into Phyre (*Kelley & Sternberg* 2009, *Nature Protocols* 4, 363–371) and protein function (CombFunc, *Wass et al*. *Nucleic Acids Res* 40, W466-W470).

Training and Support: The Graduate School delivers and monitors award-winning professional skills training for PG students, placing great emphasis on career planning, leadership and networking, as well as enhancement of personal and research effectiveness. Imperial is the only University to have won the THE Award for Outstanding Support for Early Career Researchers twice: in 2006 for innovative and integrated approaches to supporting young academics within the Graduate School, and in 2008 for initiating a course entitled "Finish Up, Move On", covering thesis writing, the viva, and careers planning. DoLS provides discipline-specific training, with aims to a) provide training in research methodologies equipping students to undertake their research projects efficiently; b) use information technology to search for, process and present information; c) present written, graphical and oral summaries of research to different interest groups and communicate science effectively. In addition to the above skills, PhD students are exposed to a broad range of research areas, and attend monthly Departmental seminars. Pastoral support is provided by 2 Postgraduate Tutors (PTs, who also act as Disabilities Liaison Officers), and the DPS if and when necessary. In addition, College Tutors, the Health Centre, the Counselling service, and the Student Union Welfare Office provide support. PG student representatives are members of all departmental PG committees, and there is a cross-campus dedicated PGR staff-student committee. DoLS organises social events throughout the year to facilitate networking and cohort building. We also organise and fund Research Days for all 2nd and 3rd year PhD students (poster and oral presentations) at which they present their research to their peers and academic staff. The Department presents awards for best posters and presentations, and additional awards for excellence in science communication.

Progress monitoring: DoLS employs a robust monitoring system to ensure that all PhD students complete their research and submit their theses on time. Our 4 year submission rate over the period is 91%. Students have 2 members of academic staff appointed to their Progress Review Panel (PRP). At 6 weeks post-registration the students, in consultation with the supervisor, prepare a formal research plan which is submitted to their PRP for comment and discussion. Following Graduate School procedures, students produce a written report of their research at 9-12 months, and again at 18-24 months, and are assessed by their PRP following a *viva voce*. DoLS has instigated additional monitoring every 6 months throughout the PhD years in the form of a brief report by the student and comments on progress by the supervisor. Every 6 months, students also complete a self-assessment questionnaire that helps them reflect on their performance and identify strengths and weaknesses, followed up by the DPS and PTs.

d. Income, infrastructure and facilities

Research Income: Over the REF period, grants awarded totalled £146M (£136M from 01.08.08-31.07.13, illustrated below by source) from 103 funders, with research expenditure of £111M). Large (>£1M) grants held numbered 48, with a total value of £82.4M. Wellcome provided the greatest (25%) proportion of these, although the largest grant awarded during the period was £12.05M to *Burt & Crisanti* by the Bill & Melinda Gates Foundation (2012-2016).

	Grants Awarded: £K				
Funder Group	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
BIS Research Councils	£15,668	£10,173	£8,346	£13,680	£14,601
UK-Charities	£5,614	£6,397	£3,882	£3,460	£7,217
Non UK Charities	£84	£333	£3,032	£1,972	£11,351
EU COMMISSION	£7,071	£9,612	£827	£3,280	£1,893
Industry	£612	£1,907	£1,370	£561	£73
Other sources	£178	£1,123	£301	£331	£860
Grand Total	**£29,229**	**£29,547**	**£17,759**	**£23,284**	**£35,996**

Two large EU consortia grants kept income high in 2008-2010, and the 2010-11 figures highlight the position at the time of the restructure, which brought our academic staff numbers down to 64. The last 2 years show the results of a remarkably successful restructure: the value of grants awarded in 2012-13 is double that in

2010-11, with academic staff numbers up to 87. Funding from BIS Research Councils is back to strength, and there has been a marked increase in charitable funding from 23.9% to 36.6% overall, due largely to major awards from the Bill & Melinda Gates Foundation, followed by UK Charities. Recent success in ERC awards is expected to increase our income from EU sources.

Investment

Space and Infrastructure: DoLS occupies 13,430m^2 of building space on the South Kensington campus and 4,400m^2 at Silwood Park, with 57.5% of total space allocated to research. Over the REF period, we spent £4.15M in refurbishing 1600m^2 of laboratory space, relocating staff and building specialised facilities such as the Ultrafast Spectroscopy Laboratory, the Microbial Ecology Laboratory, and the "GroDome", a rooftop greenhouse with 216m^2 of temperature and light controlled space. Planned refurbishment includes new insectaries with a P3 containment suite (£120K, 165m^2); upgrade of ICT (£60K)**,** and establishment of the **GCEE** centre (£1.5 million, 245m^2). We make extensive use of the 100ha estate at Silwood Park. New planned experimental facilities for field experiments and testing technical solutions will provide a focus for collaborative research projects: these include over 100 artificial ponds and streams, 30 controlled-temperature rooms, and a 'Metatron' consisting of 100 interconnected environments with full control of light, temperature and moisture. The Membrane Protein Lab (MPL) (180m^2 lab and 100m^2 office space) is a joint venture between Imperial College and Diamond Synchrotron Light Source. In addition to the Director *Prof So Iwata*, DoLS funds the salaries of a Lecturer, Facility Coordinator and administrator, all based at MPL. The expression and purification platform is located at the Research Complex at Harwell, and the crystallization platform at Diamond Light Source.

Core Facilities: We invest heavily in equipment and core facilities to support a multidisciplinary research portfolio in order to remain at the forefront of international competition. In the REF period DoLS invested over £6M in core facilities, detailed below. We provide dedicated support for these facilities, with rigorous management systems to ensure financial sustainability.

Research Facilities	FEC £K pa	Investment £K >2008	Assets £K
Bioreactor	66	-	325
Crystallisation Suite	105	-	230
X-ray Diffraction	132	375 (MRC)	500
Proteomics & Glycomics	209	489 (ICL)	942
Mass Spectrometry	173	321 (ICL)	412
NMR	507	326 (WT)	2,185
Electron Microscopy	482	749 (ICL & WT)	1,949
Imaging - FILM	425	154 (ICL & BBSRC)	1,501
Flow Cytometry	243	625 (ICL)	832
Bioinformatics	433	77 (ICL)	100
In Vivo Imaging	117	425 (MRC)	425
Insectaries	162	91	51
Plant Growth	204	2,760 (ICL)	-
GIS Laboratory	67	33	28
Field Facilities	90	62	62

Core facilities are funded with Full Economic Cost (FEC) in excess of £3.4M per annum, and have benefited from over £6M of investment over the period. They are available to all staff and students in the Department, and in many cases to other Departments in the College and external users. FILM was set up in 2006 with £1.77M from SRIF, ICL, BBSRC and the British Heart Foundation, and has just received £740K from the BBSRC Advanced Life Sciences Research Technology Initiative for a super-resolution microscope. Central Biomedical Services (CBS) is the main animal housing unit serving DoLS staff on the South Kensington campus. With 1250m^2 space and 80 rooms, CBS provides state of the art facilities for animal husbandry, manipulation, surgery and training. Associated facilities such as In Vivo Imaging and some of our Insectaries are embedded in the CBS footprint. DoLS also supports animal work with a transgenics facility, which provides a service to assist researchers in generating and using genetically modified mice, in addition to performing re-derivation and embryo cryopreservation of mouse lines. In addition to these core facilities, DoLS has provided an additional £2.5M for research equipment to supplement that funded by external grants.

Shared and collaborative use of research infrastructure: Imperial College coordinates a central directory of research facilities, a searchable list designed to enable collaboration and improve efficiency and utilisation of existing equipment and facilities; it currently lists 871 items across the College. DoLS hosts 97 of the items listed: 67 housed in facilities and 30 in PI-led research laboratories. Specific examples of shared equipment not in facilities include laser dissection microscopes, DNA sequencers and phosphorimagers.

ICT: The College provides an extensive range of ICT infrastructure to support research. Significant examples include a very high bandwidth (4x10 GBits) connection to the Janet network. This capacity allows high rate data transfers to and from UK, European and international research establishments, fundamental in supporting research collaboration with external academic and commercial partners. The centrally managed High Performance Computing (HPC) service provides research groups with access to several computer-intensive architectures, including large shared memory and massively parallel systems. In the REF period, the College has invested £5.05M in HPC, recognising its importance to research programmes, and helping to attract additional grants for the computational components of research projects as well as facilitating research which has larger HPC requirements. As an example, in 2012, research groups in DoLS ran a total of 174,145 jobs over 789,570 processing hours using the HPC service.

The **BSS** has participated in 3 major multi-institute projects over the review period: EU-SOL/International Tomato genome consortium, *FOOD-CT-2006-016214,* 85 partners in 12 countries; FP7 Malaria NoE EVIMalaR, 32 partners in 18 countries; Infrastructure for Systems Biology Europe, ISBE, 23 Partners in 12 countries, plus additional collaborations leading to publication and/or funding since with a total of 42 separate institutions in 10 countries. Within Imperial there have been over 750 different users over the REF period. The **CISBIO Mass Spec** facility was used by over 100 researchers across the college: major external users/collaborators include the Institute of Food Research Gut Health and Food Safety Programme, LSHTM, Manchester University, RVC and UCL. The **Mass Spec Quantitative Analysis** facility has an average of 25 internal users, and 8 external users (Exeter, Aberystwyth, Oxford, Cambridge, Greenwich, Rothamsted Research, James Hutton Institute, INRA Versailles, 6 of these as named collaborators on joint BBSRC-funded grants), and 2 external users for contract analysis (Warwick, Cranfield). The **X-ray diffraction facility** has an average of 25 active users (35 external collaborations over the period, e.g. NIMR, John Innes Institute, GSK, UCSF, Peking U), and the **crystallization robot** has been used by over 40 labs. The **EM Centre** had 25 collaborators over the period (e.g. Manchester, Politecnico di Torino), whereas the **NMR Centre** collaborated with numerous internal and over 54 outside users over the period, both national (NIMR, CRUK LRI & ICR, DSTL, UK universities) and international (Walter Reed AMC, NIH, MIT, Academia Sinica, Pasteur Institut Paris).

Flow cytometry has an average of 115 active users throughout the College. The **FILM facility** has contributed to 101 peer-reviewed publications since 2008. In 2012-13, **FILM** had 243 individual users from 108 groups, 4 external (Brunel, Southampton, Kings College London and a TV production company) and hosted 176 training sessions. The **insectaries** have been heavily used by over 20 internal PIs, and around 30 major external users or collaborators over the period, e.g. Oxford/Jenner Institute/Southampton. MVI, Fraunhoffer Institute (malaria vaccination studies, Wolbachia biology), LSHTM, LSTM, NIMR, Keele, Montpellier, Beirut, Perugia, IMBB Crete (malaria transmission), Texas (gamete fertilization), GSK, MMV (anti-malarial drugs), and a major EU-funded research infrastructure/integrating activity project (INFRAVEC) with over 40 PIs. **Plant growth facilities** have been used in 4 major external collaborations (Rothamsted, BBSRC BSBEC national bioenergy centre, James Hutton Institute - BBSRC HAPI consortium, Cambridge, Universiti Putra Malaysia), and by 15 internal groups. More than 100 users a year use the **GIS Lab**'s facilities for visualisation of field data, preparation of maps, interpretation of satellite imagery, global datasets, spatial statistical analyses and preparation of research proposals. Perkin Elmer and Danone Research collaborate with *Frankel* using the **IVIS Facility**, the latter with regard to the effects of probiotics and the former with respect to improving design specifications of the machine. The **Transgenic** facility mostly serves internal users, with occasional external use such as King's College London. The **MPL** has around 42 projects in progress from over 33 academic institutions and industry (e.g. Dundee, Nottingham, Leicester, NU Ireland, LMB, UCLA, McGill, Harvard), plus 7 projects from RCaH researchers, and is open

to collaborations with industry for non-proprietary research projects.

Significance of major benefits-in-kind (including, for example, donated items of equipment, sponsorships secured, or other arrangements directly related to research): We have 2 endowed Chairs: the Rank Chair of Physiological Biochemistry, and the AXA Chair in Biosphere and Climate Impacts (5 year award). Most equipment is purchased with external and department funds, with a few donated items. In 2008 the **NMR Unit** received a donation of an Oxford Instruments 600 MHz cryo-magnet from Bruker Biospin Ltd (normal cost >£300K), on-site installation and 18 month warranty, and the **BSS Unit** received a BBSRC proteomics and e-science training initiative grant to run a course on high throughput computing for bioinformatics, with *LifeTech* donating small items of computing hardware for participants.

Policy and practice in relation to research governance: The College has adopted the Council for Science and Technology universal ethical code for scientists, and upholds its 3 principles: Rigour, Honesty and Integrity; Respect for Life, the Law and the Public Good; Responsible Communications: Listening and Informing. The HoD ensures that these principles are universally adopted by staff. The College ordinance is drawn to the attention of all new staff in inductions, regularly raised in staff meetings and PRDP discussions, and awareness passed from PIs to postdocs and students in their group. The College also has a Scientific Misconduct Policy to deal with any transgression from these principles. Research proposals involving human subjects and animals are submitted to consideration by Imperial College Research Ethics, and Animal Welfare and Ethical Review Body committees, prior to grant submission or application for Home Office Licences. Applications consider practices leading to Replacement, Reduction and Refinement of methods in animal research. This is actively promoted by DoLS, and we have been awarded 1 N3CRs David Sainsbury Fellowship in Biomedical Informatics, and 2 NC3Rs PhD studentships over the period. Investigators comply with all the legislation relevant to their field of study, including that of external bodies as well as internal bodies such as the College's Health and Safety Unit and Occupational Health Service. We adhere to the principles governing authorship, specifically that that all co-authors should have made a significant intellectual or practical contribution. Primary data is recorded promptly, accurately and permanently, entries are signed and dated by the investigator in lab notebooks, which remain in the laboratory where it was generated for no less than 10 years. We are moving towards electronic recording of all primary data, and the Bioinformatics Support Service recently designed software to be used on hand-held devices for recording data (LabBook: A Digital Lab Notebook). DoLS funded the purchase of tablets for representative groups to trial this software, and we were recently awarded a BBSRC Follow on funding Pathfinder award to explore the potential for commercialising the LabBook software. This will assist researchers to be compliant with good laboratory practice and RCUK guidelines for data sharing and data persistence.

e. Collaboration or contribution to the discipline or research base

Advisory Boards: Sixty one DoLS staff have served on 276 advisory boards during the REF period. UK service is exemplified by *Beddington* (Honorary Principal Research Fellow), the UK Government's Chief Scientific Advisor from 2008 to 2013, *Buck* (Government Office for Science), *Crawley* (Kew Gardens Trustee and Chair, Conservancy Research Advisory Committee), *Dell* (RS/RAE Advisory Committee for the National Physical Laboratory), *Freemont* (UK Synthetic Biology Roadmap Co-ordination Group), *Fisher* (DEFRA Committee on amphibian health), and *Sternberg* (Advisory Board, Institute of Food Research). International advisory board membership includes the French Agence Nationale de la Recherche (*Franks*), European Food Safety Authority (*Frankel*), Health Research Board Ireland (*Williams*), Ministry of Education Singapore (*Nixon*), Luxembourg Science Foundation (*Stumpf*), French Atomic Energy Commission (*Rutherford*), Tourism Research Advisory Panel, South Africa, and IUCN Advisory Committee for identifying Key Biodiversity Areas in Africa (*Knight*), Max Planck Institute for Terrestrial Microbiology (*Filloux*), EU-NMR External Advisory Committee (*Matthews*), DEFRA/DFID's Darwin Initiative Expert Committee (*Milner-Gulland*), and the Royal Society-Leverhulme-DFID Africa Grants (*Savolainen*). *Kafatos* was the founding President of the European Research Council until 2010 and remains Honorary President. Our staff also hold leadership roles in a variety of national and international networks and consortia. These include the Diamond Light Source (*Iwata, Freemont*), the NIH Consortium for Functional Glycomics

(*Dell, Drickamer, Haslam*), the Genome 3D Consortium (*Sternberg*), Intergovernmental Panel on Climate Change (*Prentice*), EPSRC's new SynbiCITE centre for synthetic biology (*Freemont*), Board of Governors, Society for Conservation Biology (*Knight*), Terrestrial Ecosystem Research Network (*Prentice*), and the Gates Malaria Review Group (*Sinden*). *Rutherford* and *Dell* have served as Presidents of the International Society of Photosynthesis Research and Society for Glycobiology, respectively.

Peer Review: Of submitted staff, 24 have served on Research Council and Charity peer review committees over the period, including BBSRC, MRC, NERC, STFC, Wellcome, Royal Society, CRUK and the British Heart Foundation. *Dallman* is a Director and Trustee of the Francis Crick Institute. Senior Research Council roles have included BBSRC Council (*Dell*), BBSRC Strategy & Research Advisory Boards (*Dallman*), MRC Molecular & Cellular Medicines Board (*Freemont*), MRC Infection & Immunity Board (*Dallman*), STFC Science Board (*van Thor*) and MRC Neurosciences & Mental Health Board (*Wisden*). Thirty four members of staff have served on international grants committees including the NIH, ERC, WHO, NSF, Bill & Melinda Gates, EMBO, Max Planck, CNRS, Swiss National Science Foundation, Austrian Science Fund, Norwegian Research Council, Netherlands Organisation for Scientific Research, the German Research Foundation, Australian and Canadian MRC, New Zealand Biological Research Council, the Hong Kong Government Science Fund and the Russian Skolkovo Foundation. DoLS staff include 5 Editors-in-Chief of scientific journals: *Crisanti* (Pathogens & Global Health), *Knight* (Conservation Letters), *Stumpf* (Statistical Applications in Genetics & Molecular Biology), *Filloux* (FEMS Microbiology Reviews) and *Milner-Gulland* (Applied Ecology); 8 Associate Editors including *Sternberg* (Journal of Molecular Biology) and *Savolainen* (Evolution and Systematic Biology). *Nixon* and *Rutherford* have served as guest editors for Proc. Natl. Acad. Sci USA and 47 staff are on editorial boards of over 60 journals including Journal of Biological Chemistry, Biological Reviews, Nature Scientific Reports, Neuroscience, Proceedings of the Royal Society, Matrix Biology and Current Opinion in Chemical Biology.

Conferences and Named Lectures: Staff are regularly invited to participate in national and international conferences and workshops. During the REF period, plenary and keynote invitations totalled in excess of 200 at elite international meetings including Gordon, FASEB, Keystone, EMBO, Jacques Monod and FEBS conferences, with many hundreds more at the premier specialist conferences. Named lectures include: EMBO Lecture (*Freemont*), Wesley Bourne Memorial Lecture, McGill University (*Franks*), Balzan Prize Lecture, Berne (*Lande*), Annals of Botany Lecturer, New Zealand (*Nixon*), Huxley Lecture, Systematics Association (*Purvis*), Total Lecturer, European Bioenergetics Conference Dublin (*Rutherford*), and the Miegunyah Lecture, Melbourne (*Stumpf*).

Learned Societies and Honorary Degrees: DoLS hosts 6 Fellows of the Royal Society, with *Buck, Lande* and *Franks* elected since 2008. *Dell* and *Franks* were elected Fellows of the Academy of Medical Sciences during the REF period. Since 2008, 8 members of staff became Fellows of the Society of Biology, 1 was elected Honorary Fellow of the Institute of Zoology and 3 became Fellows of the Linnean Society. *Freemont* and *Rutherford* were elected to EMBO, *Endres* was elected a foreign fellow of the American Physical Society, and *Dallman* was elected a Fellow of the City & Guilds of London Institute. Honorary DSc degrees were awarded by 4 universities in Australia, Canada and Sweden (*Dell, Franks* and *Rutherford*). In addition, *Dell* was recognised for services to science by the award of a CBE.

Fellowships, awards and prizes: For submitted staff, these include 49 named Fellowships as follows: the AXA Research Fund Chair in Biosphere and Climate Impacts (*Prentice*); 1 Royal Society Research Professorship (*Lande*); 1 BBSRC Professorial Fellowship (*Iwata*); 10 Royal Society Wolfson Merit Awards (*Burt, Filloux, Milner-Gulland, Purvis, Rutherford, Savolainen, Stumpf, Zhang, Lloyd, Araújo*); 3 Wellcome Trust Senior Investigator Awards (*Hohenester, Matthews, Zhang*); 1 Wellcome Trust New Investigator Award (*Baum*); 2 Wellcome Trust Senior Fellowships (*Hohenester, Rudenko*); 1 NERC Advanced Research Fellowship (*Raymond*); 4 RCUK Fellowships (*Christophides, Ewers, Cota Segura, Orme*), 4 Royal Society URFs (*Bell, Drew, Pinney, van Thor*); 4 Wellcome Trust Career Development Fellowships (*Artavanis-*

Tsakonas, Guerra, Low and McMullan); 2 MRC Career Development Fellowships (*Hare, Lawniczak*); 1 BBSRC David Phillips Fellowship (*Murray*); 2 NERC Independent Research Fellowships (*Banks-Leite, Rosindell*); 2 Imperial College Junior Research Fellowships (*Friman, Gilestro*); 2 EMBO short-term fellowships (*Bubeck, De Simone*); 8 ERC starting grants (*Bell, Brazeau, Endres, Ewers, Isalan, Jones, Lo Celso, Windbichler),* and 1 ERC advanced grant (*Savolainen*).

Prizes in the REF period include: the Balzan Prize in Theoretical Biology and the Oxford Weldon Medal (*Lande*); the Institute of Physics Rosalind Franklin Award and the Blaise Pascal Medal of the European Academy of Sciences (*Morris*); the Robert Koch Gold Medal and the Leibniz Medal 2011 (*Kafatos*); the Karl Meyer Award of the Society for Glycobiology and the International Glycoconjugates Award (*Drickamer*); Cozzarelli Prize, US National Academy of Sciences (*Leroi*), the Royal Society of Chemistry Carbohydrate Award (*Haslam*); the Bi-centenary Medal of the Linnean Society (*Barraclough*), and the British Ecology Society Marsh Award (*Milner-Gulland*). Awards to new DoLS staff, prior to appointment, have included the Merck Millipore Research Medal of the Australian Society for Biochemistry and Molecular Biology (*Baum*), the CAPES Prize for the best PhD thesis in Brazil (*Banks-Leite*), the 2013 MacArthur & Wilson Award (*Araújo*), and the Sherman Eureka Prize for Environmental Research (*Possingham*). The fact that DoLS has been successful in recruiting exceptional talent from around the world to posts in strategically important areas of bioscience attests to the high international visibility of the Department and its attractive interdisciplinary research environment.

Academic collaboration: Of the 780 grants to DoLS staff over the period, 127 awards (16%) were collaborations with Imperial investigators outside DoLS, in the Departments of Bioengineering, Chemistry, Computing, Centre for Environmental Policy, Grantham Institute, Maths, Physics and 22 Departments in Medicine. Of the 3327 published outputs from DoLS staff, 335 (10%) included colleagues in other Departments, with a steady rise from 7% in 2008 to 12% in 2013. Co-authorship on outputs equate to collaborations with >200 institutions outside the College in 30 countries. These include Institutes and Centres in the UK which have cognate research interests such as Rothamsted Research, John Innes Centre, Institute of Food Research, Pirbright, Animal Health and Veterinary Laboratories Agency, London School of Hygiene and Tropical Medicine, Sanger Institute, MRC-NIMR, MRC-LMB, NERC Centre for Ecology & Hydrology, and Microsoft Research. Examples of collaborations include systems biologists from DoLS (*Sternberg, Stumpf, Endres and Pinney*) collaborating via a joint Institute Strategic Programme Grant with the Gut Health and Food Safety team at the BBSRC-funded Institute of Food Research, and staff from the Bacterial Pathogenesis theme collaborating with *Dougan* and *Wren* at Sanger and LSHTM. Affiliations of international collaborators include the premier universities in the major EU countries, EMBL, 3 Max Planck Institutes, Institut Pasteur, Russian Academy of Sciences, CSIR South Africa, Australian National University, University of Hong Kong, Kyoto University, University of British Columbia, Harvard, Stanford, Notre-Dame, Rockefeller, Caltech, Cornell, Yale and the Scripps Research Institute.

Collaboration with industry and other external bodies: The majority of DoLS staff regularly engage with industry via one or more of the following mechanisms: (i) research collaborations funded by industrial grants and contracts that have totalled £5.73M during the REF period, exemplified by Iwata working with GSK on drug design targeting G-protein coupled receptors, *Frankel* working with Novartis on development of pan-*E. coli* vaccines, and *Sternberg* who, together with *Muggleton* (Department of Computing) received £1.7M from Syngenta to establish the Syngenta University Innovation Centre (UIC) on Systems Biology, applying mathematical modelling to food security research questions. Professor *Stuart Dunbar* (Senior Syngenta Fellow) has stated that “The UIC has enabled us to evaluate hypotheses in key business areas that would have been impossible without predictive systems biology, It has also strengthened the relationship with Imperial across the board”; (ii) advice/consultancy to industry: a total of 21 staff, assisted by Imperial Consultants, have undertaken 81 consultancy projects for 65 clients from the industrial, financial and legal sectors during the REF period; *Drickamer* and *Taylor* are long-term advisors to Merck; *Weinzierl* is on the Advisory Board of Volition, a diagnostics company based in Singapore; *Stumpf* is an advisor to Unilever, Pfizer and SciTeb, and *Gill* gave

evidence to a parliamentary committee on the effects of pesticides on pollinating insects; (iii) involvement with spinout companies, e.g. *Morris* and *Dell* who were Chairman and Company Secretary, respectively, of the M-Scan group of companies until 2010; *Nixon* who co-founded Alkion BioPharma and sits on its Board; *Crisanti*, founder and co-director of Diagnostic Matrices Ltd (now DML-ABLogics) and Polo GGB; and *Freemont* who is co-founder and co-director of Equinox Pharma Ltd; (iv) hosting Visiting Professors from industry including *Stuart Dunbar*, *Kevin Francis* (Perkin Elmer) and *Malcolm Weir* (*Heptares*); (v) participation in academic/industrial networks (e.g. *Dell and Haslam*, together with colleagues in Chemical Engineering, are members of BBSRC's Bioprocessing Research Industry Club, and a newly awarded BBSRC Network in Industrial Biotechnology and Bioenergy, led by Manchester University); (vi) 47 CASE studentship placements in 27 companies in the REF period; (vii) supervision of undergraduate students for Year in Industry degrees (109 placements during the REF period); (viii) hosting lecturers from industry for DoLS MSc courses (e.g. from Unilever, Marks&Spencer, Shell, GSK and Celltech).

Responsiveness to national and international priorities and initiatives: DoLS staff have contributed to the formulation and implementation of numerous national and international bioscience priorities during the REF period. Examples include: *Dell* serves on the sub-group of BBSRC Council charged with BBSRC's Strategic and Delivery Plans; Imperial is one of BBSRC's strategic partner universities and *Dallman*, in her capacity as FoNS Dean, has monthly teleconferences with BBSRC's Executive Director, Corporate Policy and Strategy; *Freemont* is a member of the UK Synthetic Biology Roadmap Coordination Group and is co-author of "Synthetic Biology - A Primer" which gives a broad overview of the emerging field of synthetic biology; *Drickamer* has played a pivotal role in defining research priorities of the NIH Consortium for Functional Glycomics; *Filloux, Frankel, Fairweather* and *Matthews*, together with colleagues in Medicine, established the CMBI which addresses a major MRC priority of antibiotic resistance; CISBIO (*Stumpf, Sternberg, Endres* and *Pinney*) and CSynBI (*Freemont*) have received substantial strategic funding from BBSRC, EPSRC and the EU; *Nixon, Rutherford* and *Murray* are engaged in Imperial's Artificial Leaf project, closely aligned with RCUK's energy grand challenge; *Savolainen, Milner-Gulland* and colleagues, through the GCEE, address Cross-Council priorities *Living with environmental change*, and *Lifelong health and well-being; global food security*. Priorities and initiatives are dealt with in section b in more detail.

Mechanisms to promote collaborative research: Collaborations and productive engagement with the user community are the norm in DoLS as exemplified by co-authorship of REF outputs and the numerous interactions outlined in previous sections. These interactions are facilitated by the diverse nationalities of staff (e.g. USA, Brazil, China, India, Japan, Australia and the major EU countries) and by their cross-disciplinary expertise which embraces the full gamut of physical and life sciences. Mechanisms to promote collaborations with academia and research users include: (i) Pump-priming of Centres and Institutes with Departmental and Faculty strategic funds together with support staff posts; (ii) joint appointments with foreign universities and institutes, for example *Iwata* (Kyoto), *Crisanti* (Perugia), *Rahbek* (Copenhagen), *Possingham* (Queensland), *Holland-Jones* (Stanford); (iii) hosting 28 Visiting Professors from academia and industry, for example *Hart* (Johns Hopkins), *Dutton* (Pennsylvania), *Kuhlbrandt* (Max Planck, Frankfurt), *Andersson* (President Nanyang Technical University), *Wiuf* (Copenhagen), *Walker* (Cambridge), *Malhi* (Oxford), *Weir* (Heptares), *Francis* (Perkin Elmer), *Hopwood* (John Innes): (iv) promotion policies that have the flexibility to reward the independent achievements of junior staff engaged in interdisciplinary and/or collaborative research, for example by giving full credit to co-PI status on major grants; (v) participation in interdisciplinary PhD programmes, for example Chemical Biology of Health and Disease co-ordinated by the Department of Chemistry at Imperial; (vi) DoLS periodically organises focus meetings and workshops to promote synergies, collaborations and strategic initiatives both within the department and across the College. Topics have included Host/Pathogen Interactions, Food Safety & Security, College Facilities Showcase, and Impacts of Climate Change; (vii) The Head of DoLS works closely with Imperial Consultants to maximise opportunities for staff to engage with research users.