Institution: Imperial College London

Unit of Assessment: 5 Biological Sciences

a. Context

The Department of Life Sciences (DoLS) has an extremely broad range of research activities, organised into 12 themes (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). The research undertaken in DoLS has had substantial economic, social and environmental impact benefitting a diverse range of user groups. The principal types of impact include:

Economy and commerce: Industry has benefitted through our direct collaboration with over 30 companies (including GSK, AstraZeneca, Novartis, Syngenta, Merck, Boehringer Ingelheim) from a broad spectrum of sectors including pharmaceutical, chemical, agricultural and medical industries, addressing key industrial challenges through developing new methods and technologies [cases 1-5], through the development of spin out companies [case 11] offering new products and services (8 start-up companies active during this REF period) and through patenting and licensing of new IP.

Health and welfare: Our research on new drugs and therapies has impacted healthcare and regulatory industries. Bacterial Pathogenesis groups contributed to vaccine development and analysis of the potential health benefits of probiotics, and conducted projects for the Ministry of Defence through the Defence Science and Technology Laboratory. Research by *Franks* and colleagues on the molecular mechanisms underlying anaesthesia defined the molecular target of xenon, and developed this gas as a neuroprotectant for medical applications.

Policy and International development: Through working closely with government organisations, our work has influenced the formation of public policy at local, national and international level. Engagement with the Grantham Institute for Climate Change led to research on peatlands which impacted on the UK Climate Change Risk Assessment conducted by DEFRA and briefing reports by the Forestry Commission and the Scottish Parliament [case 7]. Imperial's Fish group provided fisheries management advice to the Falkland Islands Government with unprecedented impacts on the Falkland Islands, where between 50% and 75% of the annual revenue required to fund all infrastructure, research and development in the Islands is generated by the £20M income from the sale of commercial fishing licences [case 8].

Environment: Research on biodiversity and conservation biology by existing and previous groups in our Ecosystems and the Environment theme has influenced policy set by Governments, Charities and NGOs in relation to conservation planning and environmental management, broadly informing national and international advisory groups such as the World Wildlife Fund, International Union for Conservation of Nature and the United Nations Environment Programme. Population modeling and species conservation assessment tools developed by these groups have been widely applied [cases 8, 9, 10], extending to such areas as climate risk assessment and global change biology. Research by staff working on genes, genomes & phylogeny in the Evolutionary Biology theme has influenced biodiversity organisations such as museums, botanical gardens and the taxonomic community. Development of DNA Barcoding systems for taxonomic identification of plant species has had a major impact in authenticating material for trade control, e.g. regulating the importation of invasive species, and consumer fraud [case 6].

Society: In order to raise public awareness, understanding and enthusiasm for science, we take the opportunity to disseminate our research actively through traditional and new media channels (TV, radio, web, social media) and through dedicated outreach activities including public projects, partnerships, workshops and demonstrations.

Schools: We engage in a 2-way collaboration with schools in order to enthuse children about STEM subjects. Staff give talks and our students are involved in a peer-tutoring scheme in schools in the Greater London area, and we run workshops for school students at Imperial College.

b. Approach to impact

The specific Departmental mechanisms used to create and promote impact include:

B.1 Engagement and collaboration with industry

- **Strategic partnerships:** We work with a number of key industrial and public sector partners, e.g. Syngenta, Rio Tinto, ZSL London Zoo, Natural History Museum (NHM), Royal Botanic Gardens Kew, who as well as partnering with us in individual grant applications to third party funders and directly supporting research of relevance to their business, play an important wider

role in helping us to explore research needs, provide feedback on research vision and advice on pathways to exploitation and commercial impact. Relevant mechanisms include workshops and meetings with senior industry representatives, joint funding of academic staff (2 positions funded with NHM and RBG Kew) and joint organisation of Masters courses (NHM and ZSL). Formation and development of strategic alliances that leads to research collaborations of value to both partners is supported by our Corporate Partnerships team, whereas Imperial Business Partners provides a forum for members to improve their access to Imperial, holding quarterly dinners and an annual Tech Foresight Conference with leaders from industry and academia.

- **Industrial consortia:** We organise and participate in industrial consortia, which bring together industry players to define research needs, collaboratively fund relevant research and propagate results to practice. The flagship consortium coordinated by Imperial is SynbiCITE, the Innovation and Knowledge Centre in Synthetic Biology, with 17 other academic institutions and 13 industrial partners (e.g. Microsoft, Shell, GSK), which aims to boost the UK's ability to translate synthetic biology into application, and provide a bridge between academia and industry. Participation in consortia is exemplified by Kinetics for Drug Discovery (K4DD), a €21M project coordinated by Bayer Pharma AG and consisting of 7 major companies (e.g. Hoffman La Roche, Sanofi-Aventis), 9 Universities (e.g. Dundee, Wein, Leiden) and public bodies and 4 SMEs (e.g. Heptares, Sierra Sensors GmBH). The International Pesticide Application Research Consortium (IPARC), based at Silwood, is a WHO collaborating centre which carries out research, evaluation and training on the application of control agents, with particular expertise in rational pesticide use, use of sprayers appropriate for the developing world, setting standards for application equipment and sprayer testing, nozzle evaluation, biopesticide formulation and use, and participatory training of farmers and trainers [case 5].
- **Embedded industrial R&D:** DoLS has a long history of nurturing entrepreneurial activities, and champions the concept of placing industrial R&D teams within an academic environment, with many mutual benefits. Company staff share space, equipment and facilities with academic staff and offer research projects to students, leading to cross-fertilisation of ideas and research programmes. There have been 8 of these over the period; recent examples include Image Science, which markets the IMAGIC image processing software system, and Photobiotics, which develops antibody-targeted photodynamic therapy for cancer therapy, both spin-out companies set up by our staff. The company M-SCAN [case 2] was established to commercialise the work of our mass spectrometry group. It pioneered commercial characterisation of biopolymers, and remained associated with DoLS until its sale in 2010.
- **Research centres:** The Department hosts 9 research centres, several of which provide direct channels for transmitting research outputs to industry. The Syngenta University Innovation Centre (UIC) was set up in October 2008 as a centre of excellence in Systems Biology aiming to address biological research questions of importance to Syngenta by mathematical modeling developed at Imperial. This is a cross-faculty initiative led by *Michael Sternberg* (DoLS) and *Stephen Muggleton* (Department of Computing). The Cross-Faculty Centre for Synthetic Biology & Innovation (CSynBI), an EPSRC partnership between Imperial College, London and the BIOS Centre at King's College London, has industrial collaborations which include the application of synthetic biology to bioleaching with Rio Tinto, and improvement of the quality of food products with Dairy Crest. CSynBI has an Industrial Club that organises annual meetings, with representatives from Shell, Syngenta, Lonza, Microsoft, Samsung, Synthace and other organisations. DoLS supports this centre via provision of research space and a designated lectureship in synthetic biology (see also SynbiCITE above).

B.2 Intellectual property and commercialisation

- **Intellectual property generation and start-up companies:** The Department actively encourages its staff to protect and exploit their innovations, working in collaboration with Imperial Innovations, a publically-listed company combining the activities of technology transfer and company incubation with investment. Over the assessment period, staff from DoLS have made 68 invention disclosures, 55 patent applications for 15 separate patent families, and 13 Intellectual Property deals. DoLS has founded or developed 8 start-up companies. Examples include Alkion Biopharma, which utilises technology for production of novel biopharmaceuticals in plants (*Nixon*); Microtest Matrices, which develops multiplex in vitro diagnostic tests for allergy, infectious and autoimmune diseases (*Crisanti*), and Equinox Pharma, which is a

computationally-driven logic-based drug discovery company (*Freemont, Sternberg*). Imperial Innovations also provides support to very early stage ideas with commercial application through provision of Proof of Concept funding, and examples over the last year include Florigen protein spray to induce flowering in plants (*Turnbull*) and identification of transmission-blocking anti-malarial drugs (*Sinden*). The Head of DoLS meets annually with the Deputy Director of Technology Transfer to review potential cases for development, and Innovations gives annual presentations at academic staff meetings to promote awareness of opportunities for commercialising their research.

- **Consultancy**: Staff are actively encouraged to capitalise on their specialised knowledge and expertise by undertaking external consultancy work through Imperial Consultants (ICON). Since 2008, we have undertaken 81 consulting projects for 65 distinct clients, with a total value of £1.02M. Examples include suitable plant biomass for a renewable 'PlantBottle', Coca-Cola (*Murphy*); pest control, US Agriculture and Agri-Food Canada (*Bateman*); drug development, Crucell Holland (*Matthews*); antibiotics against *C. difficile*, Summit Corporation (*Fairweather*).

B.3 Knowledge transfer

- **Exchange of personnel:** DoLS encourages staff to take full advantage of the many formal mechanisms of exchange. We see investment by research users in PG CASE awards as laying important pre-impact groundwork - 47 CASE studentships have been initiated since 2008 funded by 27 different partners including the Game and Wildlife Conservation Trust, ZSL, Alderney Renewable Energy, Microsoft Research, GlaxoSmithKline, Pfizer, Boehringer Ingelheim, Syngenta, Danone, Novartis and Merck. These are invaluable in giving PG students experience in working in a non-academic setting and in building research collaborations.
  DoLS has a tradition of appointing representatives from industry as Visiting Professors, facilitating engagement with industry and reinforcing the significance of translational research in education. For example, *Stuart Dunbar* (Syngenta Senior Fellow) is an Adjunct Professor who teaches on both UG and PG courses. He was instrumental in establishing the Syngenta University Innovation Centre on Systems Biology at Imperial (B.1), and provides valued input in defining industry needs in terms of student skills and experiences.
  Since 2008, 9 staff have taken sabbatical leave to work at outside institutions. In addition, 2 incoming sabbaticals have been funded through the Wellcome Trust Institutional Strategic Support Fund, which supports interdisciplinary and inter-institutional collaboration. *Ed Hawkins'* visit from the Peter MacCallum Cancer Centre, Melbourne to *Cristina Lo Celso* led to application of *in vivo* imaging to study leukaemia, and further funding from Leukaemia & Lymphoma Research, and the European Hematology Association.
- **Research Council and internal Impact schemes**: We have taken advantage of several Research Council Impact schemes during the assessment period. These have included an EPSRC Bridging the Gaps award (£25K) and a BBSRC Sparking Impact award for LabBook: A Digital Lab Notebook (£17K), designed to assist compliance with good lab practice in recording data. Although too early to have measurable effects, this has been supplemented with a £10K BBSRC Follow-on fund award to conduct market research on commercial development of LabBook. A 2013 NERC impact accelerator award (£39K) to *Rosindell* will be used to explore possible industrial uses of the 'OneZoom' Data Visualisation Engine beyond the 'tree of life' into genealogy, directory structures and industrial process plant monitoring applications. DoLS also supports staff in applications for Royal Society Wolfson Research Merit Awards to maximise the impact of their research, and there have been 10 recent recipients of these.
- **Training courses:** The Department runs a small number of CPD courses for outside users, such as the proteomics and e-science course (BBSRC training award, ran 3 times in the period serving 50 attendees), and a course on use of the R language in Statistics (*Crawley*, runs annually with 40 attendees, at least 5 of which are normally from industry, e.g. Syngenta).
- **Multidisciplinary interactions within Imperial**: DoLS has increased collaboration with other disciplines within Imperial via the establishment of research centres, of which 8 operate across Departments, promoting new approaches to research and leveraging new funding. DoLS contributed to the successful bid to establish a Climate "Knowledge and Innovation Community" (KIC), and Imperial hosts the UK co-location centre. Launched in 2010, Climate-KIC aims to spark and deliver innovative solutions to climate change via a dynamic alliance of European partners drawn from academia, industry and the public sector. Working across Europe, Climate-

KIC focuses on four broad themes: Measuring climate change and managing its drivers; Water management; Low-carbon cities; Zero-carbon production. DoLS provides specific expertise in measuring the effect of climate change on ecosystems and the environment, and is playing a major role in establishing a new **Institute for the Environment** at Imperial College.

B.4 Staff support

- **Staff development plans:** DoLS encourages and fosters the achievement of impact from research from the outset by advising new staff and supporting their efforts in this direction. Consideration of impact is one of the criteria adopted for recruitment of academic staff, and is now included in annual appraisal of staff via the Personal Review and Development Plan (PRDP), a key element of our HR Strategy aimed at career development and performance enhancement. Opportunities for impact are addressed at academic staff meetings, which feature regular presentations from ICON and Imperial Innovations.
- **Training:** The Imperial Centre for Professional Development (CPD) provides courses delivering the skills needed by business and industry. The Innovation and Entrepreneurship Group (within the Business School) also aids development of entrepreneurship skills via online tools and activities. DoLS staff have attended a range of courses including "Developing Business and Enterprise Awareness" and "Acting as a Research Consultant", with 212 cases of postdocs and early career researchers attending courses and 94 coaching sessions over the period.
- **Faculty funding support:** In order to promote new bids for external funding, the Faculty of Natural Sciences (FoNS) provides funding with a strong interdisciplinary incentive under its '**Collaboration Kick-start', 'Strategic Research'** and **'Creativity Lab'** schemes. Grant awards of up to £20K have the primary objective of enabling multidisciplinary teams to conduct feasibility or exploratory studies to develop such bids, with a major focus on industrial or business partners. This mechanism has provided DoLS with funding of £112K for 6 projects since the inception of the schemes in 2010, e.g. including support for Imperial's Industrial Biotechnology (IB) Hub, a multidisciplinary research network that facilitates collaboration, creativity and idea generation across Imperial and with external academic and industry partners. IB funding (£17K) supports projects that will enable our academics to develop large bids and leverage external funding. Activities supported include feasibility studies, exploratory research and visitor/exchange programmes to develop links with industrial collaborators.
- The **Networks of Excellence in Translation** scheme is supported by the Wellcome Trust Institutional Strategic Support Fund (ISSF). This fund comprises matched funding from the College and the Wellcome Trust to help further the strategic ambitions of the College, actively supporting efforts to foster high quality research, scientific exchange and translation. During the period DoLS has been awarded 2 projects totalling £211K. *Mann & Freemont* used their award on kinetic template-guided tethering to secure an agreement with a large pharmaceutical firm to screen one of their difficult targets for inhibitors (details protected by non-disclosure agreement).

B.5 Public engagement and outreach

We have significantly increased participation in public engagement and outreach activities following panel feedback from RAE 2008. Through the PRDP appraisal scheme, participation in exhibits and debates is encouraged, and 30 staff have engaged in 134 events such as the Edinburgh and Cheltenham Science Festivals, Royal Institution, NHM, Science Museum, Royal College of Art, and the Royal Society Summer exhibitions. We run 'Citizen Science' projects on biodiversity and conservation which involved over 2000 members of the public in the last 5 years, and an annual BioBlitz event at Silwood Park, sponsored by OPAL, which has engaged over 750,000 members of the public in citizen science. This year we became partners with Sense About Science, and staff joined the Plant Science Panel, which fields questions and promotes debate with the public on issues such as the environment, plants and food. *Armand Leroi* regularly presents documentary series on television, e.g. What Darwin Didn't Know (2009) and Aristotle's Lagoon (2010), radio (DarwinTunes, 2012), in addition to journalism (Observer, Guardian, New York Times), publishing popular science books, and engaging in public debate (Edge, Royal Institution, British Humanist Association). *Stephen Curry* is a co-founder and vice-chair of Science is Vital, a successful campaign to protect the science budget, and retains a keen interest in science policy through his position on the Board of Directors at the Campaign for Science and Engineering. His science blog Reciprocal Space is now part of an independent network with wide exposure via a regular slot in the Guardian (Occams' Corner) in 2012. Through this forum he tackles many broad

areas of science, e.g. “Maths for Life Scientists” which led to an article in the THE magazine and stimulated a nationwide debate, with the ideas translated into revision of our UG curriculum.
The College Outreach office has an operational partnership with Exscitec, and we have organised workshops for between 25 to 50 school students in 1 day courses for Exscitec, WISE, and London Gifted and Talented, in addition to hosting 30 students from the London International Youth Science Forum in 2013. A total of 23 staff have given 136 talks at schools on Life Sciences and STEM subjects, and our students actively participate in The Pimlico Connection, a peer-tutoring scheme in local state primary and secondary schools.

c. Strategy and plans

In order to respond to new developments and challenges, we intend to:

- Build on current strategies to maximise impact by maintaining this as a factor in selection and career development of academic staff, continuing to emphasize the importance in staff meetings, and embedding this in the culture at an early stage for PG students and postdocs.
- Expand the remit of the DoLS Research Strategy Committee to identify opportunities in which we can contribute to industrial and commercial sectors, and to make this committee the major point of contact with Corporate Partnerships and Imperial Innovations.
- Set up a formal framework beyond the PRDP to ensure that all research activities are assessed and monitored for their potential to produce impact.
- Undertake horizon scanning exercises with our strategic partners to identify major technological trends and the effect of disruptive technologies.
- Introduce new reward schemes to recognize achievements and incentivise researchers, with the aim of increasing the conversion rate of research into exploitable outcomes.
- Extend the remit of sabbaticals to translational studies and commercialization of research.
- Work with the Centre for Professional Development to identify and develop specific areas for impact-related staff training and CPD courses for outside users.
- Strengthen our impact on food security, biodiversity, global change and conservation biology by developing partnerships with relevant industries and government organisations wherever possible and relevant for large scale projects, in a manner analogous to the SAFE project.

d. Relationship to case studies

There are many examples of significant impact in the Department. We have submitted 11 case studies representing the range of long-standing mechanisms (B.1 to B.5) described in Section B, which individually and in combination, have led to impact. Our strategic approaches to translation have in turn been refined by experience over the assessment period and continue to evolve.
Cases 1 (Q-TOF) and 2 (M-SCAN) were facilitated through consultancy (B.2) and by providing resources to enable academic staff to spend time in the private sector (B.1).
Case 3 (Production of commercial biofuel from waste) was facilitated by our policy of embedding outside R&D teams within an academic environment (B.1) with one of the PhD students funded through a CASE award working with TMO (B.3).
Case 4 (Molecular Dimensions) was made possible by encouragement of commercialisation of research through Imperial Innovations (B.2).
Case 5 (Green Muscle) arose from the long history of engagement of DoLS with non-academic user groups, exemplified here by embedding IPARC on the Silwood Park campus (B.1).
Case 6 (DNA taxonomy) was largely made possible by collaboration with external partners, in this case primarily the Royal Botanic Gardens Kew and the Natural History Museum (B.1).
Cases 7-10 (Peatland ecosystems, Falklands fisheries, Saiga Antelope and IUCN Red List) all demonstrate impacts on the environment linked to policy decisions, debate, and management or conservation of natural resources. These were facilitated by the unit’s policy on encouraging engagement with external organisations and the creation of strategic partnerships (B.1).
Case 7 (Peatland ecosystems) was additionally facilitated by promotion of and engagement with interdisciplinary research centres such as the Grantham Institute for Climate Change (B.1, B.3).
Case 9 (Saiga Antelope) also demonstrates the importance of public engagement in increasing awareness of species conservation (B.5).
Case 10 (ICUN Redlist) was further enabled through *Mace’s* consultancy role with ICUN (B.2), and through the NERC Centre for Population Biology (B.1).
Case 11 (Ionscope) was made possible by encouragement of commercialisation of research through Imperial Innovations (B.2).