Institution: Imperial College London

Unit of Assessment: 8 Chemistry

a. Context

Underpinned by our five research sections, our key non-academic user group during the REF period has been industry, resulting in global economic impact. This is realised both through direct collaboration with over 100 companies (including Astra Zeneca, Shell and Rio Tinto), as well as supporting SMEs (such as AFChemPharm) and the development of spin out companies. Chemistry staff have co-founded 15 start-up companies that are active during this REF period including PhotoBiotics and Powerlase. We engage with a full spectrum of industrial sectors including pharmaceutical, chemical, biotechnology, healthcare, energy, manufacturing, consumer goods, electronics and specialties. Our strategy to foster commercial and applied research has reaped rewards; the department's industrial funding has increased by 125% since 2008, totalling over £7M during the assessment period. Based on the latest 2011-12 sector data, we received £1.8M in industry funding (3rd highest in the UK), amounting to 14% of our total research income. In addition to economic impact, other principal forms of impact include:

Professional services: Staff across all research groups participate in consultancy and advisory board membership for beneficiaries including government and industry.

Health: We support the health industry through synthesis, diagnostics and chemical biology. For example, our research on new drug treatments for use in treatment of breast cancer will shortly be used in clinical trials in both the USA and UK (2 over the period, with back up series).

Public Policy: Our research is used by several government establishments, in areas including climate, energy and health, with our staff serving on advisory boards responsible for Government policy change, including the Ministry of Defence, the Technology Strategy Board and the European Commission.

Environment: Our focus on renewable energy and green chemistry has provided the stimulus for start-ups such as Econic Technologies and Flexink, alongside coordination activities such as the Climate KIC, the Energy Futures Laboratory and the Grantham Institute for Climate Change.

Public Engagement: We seek to inspire public debate and discussion about our work, which is disseminated through traditional and new media channels (TV, radio, web, social media) and through dedicated outreach activities including public events, museum exhibitions, lectures and sessions within schools.

b. Approach to impact

Founded in 1907, Imperial College of Science and Technology was the first UK university to have the application of its work to industry and commerce as central to its mission. Knowledge transfer and the commercial exploitation of research through industrial engagement are integral to the activities of the Chemistry Department, facilitated by our outward facing research sections which are focussed on exploiting our innovations and capability.

Approach to staff interactions

i) Advisory boards: We impact the technology strategies of global industry through membership of company advisory boards. During the REF period, over 50% of our academic staff participated in more than 100 consultancy or advisory boards across all key user group organisations. One industrial example is the Samsung CORE Advisory Board, where, since 2010, we have provided advice on commercialising organic photovoltaics. Other examples include serving on the National Gallery Science Advisory Board, the DEFRA UK Chemicals Stakeholder Forum, the Royal Society Education Vision Project panel and on the boards of educational charities such as Lloyds of London Tercentenary Foundation.

ii) Government: Staff provide expert advice to several government agencies. For example, in the UK, we worked with Oxford Economics on the 2010 report 'The Economic Benefits of Chemical Research', which was acknowledged to be instrumental in shaping the subsequent science budget by Minister for Universities and Science, David Willetts. We worked with the European Parliament on Climate Change, participating in a range of strategic policy decisions regarding funding, research and education.

iii) Consultancy: 30 members of our current staff actively engage in consultancy with a broad range of industrial organisations, with over 115 contracts executed from sectors including consumer electronics (Samsung, CDT), energy (BP, Ceres Power), and pharmaceuticals (BMS, Sanofi-

Aventis, GSK, Pfizer, Lilly, Genzyme). The expertise provided includes advice on process improvements, research strategy and new materials development. For example, a consultancy with Cardiome led to the development, through clinical trials, of the cardiovascular drug Vernakalant, which, in 2010, was approved for sale in the EU. Consulting activities with Rio Tinto have resulted in a licensing agreement of the software code CRYSTAL. Since 2007/8, ICON has brokered 45 commercial consulting projects between researchers in the Department of Chemistry and 37 external clients, generating £707k in consultancy income.

iv) Technology transfer: Imperial Innovations, founded as the technology transfer office of Imperial College London, supports academic staff to create and exploit pioneering technologies. The Chemistry department has appointed an "Innovations Fellow" to strengthen links with Innovations and thus support technology transfer activity. Since 2008, Chemistry staff have had 123 Invention Disclosures submitted and assessed for IP protection and commercialisation. Based on 139 patent filings in the period, 53 separate families of patents have been published, with 7 assigned or licensed to external industrial companies. In addition, since 2008 Innovations have helped spin out 3 companies from Chemistry research, raising funds in excess of £14.6M (Plaxica, Econic Technologies, Mycologix), as well as out-licensing technology from the department, including Flexiplanar fuel cells and the software code GULP, to a wide range of licensees including Lockheed Martin and BNFL. Several start-ups have also been co-founded by department staff (including Linde Nanomaterials, Flexink and Nanoneedles).

v) Knowledge transfer: Our success in EPSRC impact schemes has included 11 Knowledge Transfer Secondment (KTS) grants to support the secondment of staff into organisations and 5 KTS grants for incoming staff, 10 Pathways to Impact grants (totalling £529k), 45 CASE awards and 6 Doctoral Prize grants (£410k). This has allowed us to out-place four postdoctoral researchers in Merck Chemicals, Solar Press, Molecular Vision and Flexink. Other examples of are the placement of 4 PhD students and PDRAs in Genentech (US), and a successful collaborative project with Millennium Chemicals that has enabled the company to evaluate the viability of incorporating microreactor technology into their production manufacturing lines. We have also been involved with 6 Confidence in Concept grants (Wellcome Trust and MRC funded - £483k) since 2008.

Each year, the department enters into several CASE award agreements with external bodies to enable PG students and their supervisors to work closely with research users. From 2008-2012, our 45 CASE awards included partnerships with 23 organisations including AWE, BP, GSK, Astra Zeneca and Merck.

Workplace training is provided for Industrial Embedded Researchers. Four industrial scientists (from Thomas Swan Ltd, Solvay, Rhodia and Solar Press) have been hosted to engage in technology transfer with our researchers. Thomas Swan Ltd placed a chemist in the department in 2012 to train in the nanofunctionalisation technology which they had recently licensed; he returned to the company to build a pilot plant based on the technology.

We deliver courses and lecture series for industrial partners. Over the REF period, we delivered over 30 courses to over ten partners including Unilever, Merck, INEOS and Boehringer Ingelheim, with a total of over 2000 participants.

vi) Industrial Networks: Our department has an External Advisory Board, responsible for the alignment and calibration of the strategic research direction and on-going business plan with our main non-academic beneficiaries. The board comprises senior representatives ranging in provenance from chemical companies (e.g. Ineos, Heptares Therapeutics) to venture capital organisations (such as Natrium and CVC Capital Partners) and supports the department in realising its strategy of maximising impact to end-users.

During the REF period, the Department has had three Centres for Doctoral Training (CDT) in the Institute of Chemical Biology (ICB), the Science of Plastic Electronic materials, and the Theory and Simulation of Materials, within the Thomas Young Centre (TYC) – a collaboration with UCL. The ICB CDT is developing an Open Innovation Technology Framework bringing together over 30 companies including GSK, Syngenta, Astra-Zeneca and Procter & Gamble. The Centre for Plastic Electronics (CPE) hosts a growing Industrial Affiliates Program, with over 20 member institutions including Bayer, Dow Chemical, Plastic Logic, and Samsung. Industry is financially committed to the programme by, for example, currently funding 7 post-doctoral researchers engaged in work leading to new products and research directions. The first industrial demonstration of a scale-up of a high performance solar cell polymer was achieved in partnership with Solvay in 2013, initiated

through the CPE Affiliates Program.
Our staff have co-founded and organised wide-reaching consortia. These include the Pharmacat consortium involving AstraZeneca, GSK, Pfizer, Syngenta and Lilly. Initiated and organised by the Chemistry Department, it coordinates and funds pre-competitive research on innovative green and efficient chemical technologies for the production of pharmaceuticals. Agri-net, with 240 members from institutions such as Syngenta, Bayer, Sainsburys and DuPont, is Imperial Chemistry-led with members of the agri-science and chemical biology community working in partnership with industry and policy makers. An Agri-net drafted "Landscape" document has been commissioned by BBSRC to shape policy in agri-science in the UK. PPI-Net is an academic-industrial collaborative network founded and run jointly by Imperial College, currently consisting of 82 academic and 60 industrial members in protein-protein interactions for new drug targets.
vii) Public engagement: Staff participated in over 50 broad media programs on radio, television, print and online, including BBC News, Newsnight, Breakfast TV, Radio 4 Today and Radio Five Live, providing expert commentary on science news stories. Our staff have also given talks to the public on various themes including Green Chemistry, Energy and Nanotechnology. One highlight was the 2012 Queen's Anniversary Lecture in Berlin, 'Prosperity Though Chemistry' sponsored by the British Council and UK Embassy, with an audience of 1000.
viii) Outreach: We fund a dedicated outreach officer who coordinates public lectures, school talks and laboratory sessions (over 70 in the period), as well as PhD placements within schools, work placements and summer schools. In collaboration with the Royal Society of Chemistry, the department organised the London Schools Chemistry Challenge, a competition open to all students studying Chemistry (GCSE or A-level) in Greater London.1300 students registered to take part from 250 schools across London. In addition, the Department of Chemistry Work Experience Programme allows school pupils to spend time in our department.

Supporting and enabling staff to achieve impact

Mentoring of junior staff is an integral part of the department philosophy. We introduce all new members of academic staff to relevant companies and other end users by, for example, arranging meetings with the industrial partners of our consortia (e.g. PharmaCat) and centres. Research collaboration funding by Shell (£720k) resulted from such an introduction. New staff are required to meet with both Innovations and ICON as part of their induction programme
The department supports a culture of innovation and entrepreneurship through, for example, the coordination of an annual Dragons' Den style competition, showcasing PhD student entrepreneurship. The finalists receive guidance in entrepreneurship from Imperial College Business School and intellectual property patenting advice from Imperial Innovations to refine their pitches, as well as prize money for developing the winning concept.
From 2013 onwards, all departmental procedures associated with career development include a discussion on how the candidate has sought to develop impact from his/her research. These include the annual Personal Review and Development meeting for all staff as well as probationary staff reviews and applications for promotion. This has been externally recognised by an Athena Swan Gold Award and two Athena Swan Silver Awards as examples of best practice in staff career development.
The College's Centre for Professional Development provides courses designed to deliver highly trained people with the skills needed by business and industry. The Postdoctoral Development Centre provides a programme of development activities that supports the personal and professional development of the 2000 postdoctoral researchers at Imperial. One measure of the success of this programme is that close to 80% of synthetic chemists are placed in industry.

Other Institutional resources

The Faculty of Natural Sciences additionally runs schemes to help staff establish multi-disciplinary activities which have the potential for innovative research in strategic areas. In the REF period these have included funding 4 Chemistry-led 'Creativity Lab' brain-storming groups and 15 Kickstart Funding awards for new collaborations, totalling £268k. In allocating the funds, key consideration is given to the potential future impact of the activity.
The Imperial Business Partners Programme (IBP) seeks to tackle shared strategic issues through open and thought-provoking dialogue between Imperial's industrial partners and the College's science, technology and business experts. Chemistry has made major contributions to IBP with key speakers at the IBP Tech Foresight conferences in 2012 and 2013.

c. Strategy and plans

In the future, we will continue to use the approach outlined in section b, to ensure the potential impact of our research work is maximised. Specifically, we will:

i) Continue to increasingly focus our research on outward facing research themes that are flexible and dynamic, enabling us to respond to changing external environments. We will continue to build industrial consortia for pre-competitive research (like PharmaCat) that will also act as advisory boards for these themes.

ii) Strengthen further the Chemistry Department Advisory Board through the addition of representatives from the third sector and government. Our intention is to invite representatives from the EPSRC, BIS, the Leverhulme Trust and Wellcome Trust for participation from January 2014 onwards.

iii) Continue to support staff to develop impact from their research, through continual communication through their PRDP process, probationary reviews and applications for promotion. Impact will from a criterion for success. Since May 2013, Impact achievements have been included in the weekly "celebration of success" emails sent from the Head of Department to the department and faculty.

iv) Include impact activities in the Department's workload model, liberating time for impact activities. Alongside this, we will develop an active media strategy to better inform potential research users of our successes, including a periodical online magazine.

v) Continue to increase the number of staff who are members of external advisory boards through increased communication of advisory board positions when they become available.

vi) Encourage and support our staff further by coordinating seminars to be given both by Innovations and Partners in City Venture Funds and initiate drop-in sessions for staff giving them the opportunity to discuss ideas one-to-one with Innovations and ICON.

vii) Strengthen and grow our existing inter-department and cross-university networks including Climate KIC (see REF5), AgriNet, and PPI-Net. In addition, the recent initiative, Laboratory for Translational Molecular Research, is a cross-Faculty collaboration that aims to link Imperial's world-leading strengths in Science, Technology, Engineering and Mathematics with its world-class clinical strengths through the creation of a unique centre for the discovery of small molecule and biologic medicines, molecular diagnostics and the understanding of biological processes. With circa £4M investment from College funds this will be achieved by establishing a critical mass of ~40 scientists and engineers on the College's West London campuses in early 2014.

viii) Nominate 5 'Impact Champions' from amongst the academic staff to be the vehicle for fostering interest in translation among new academic staff and those who do not normally engage in exploitation activities. Support will include mentoring and provision of advice on balancing the often competing demands of attracting research funding, publishing and research translation.

d. Relationship to case studies

The impact case studies reflect the broad variety of department activities and innovative culture, translating research into commercial propositions, including industrial application of technology, spin out companies, software development and commercialisation, and public (or non-academic) engagement. Case C1 (Argenta) was facilitated by *AGM Barrett's* advisory board membership on the global Board of Scientific Advisors in Medicinal Chemistry at Rhône–Poulenc, and Chemicals Panel of the Technology Foresight Programme for the Office of Science and Technology. Cases C2 (Molecular Vision) and C3 (Plaxica) were supported via Imperial Innovations. Cases C2 and C4 (Bio Nano Consulting) were also supported at an institutional level via KTS, BBSRC and the Royal Society. Cases C2 and C4 have arisen from interdisciplinary work with the Department of Physics, and C5 (Mazarin Chest) have arisen from interdisciplinary work with the V&A. An Arts and Humanities Research Board funded Collaborative Doctoral Award was critical for case C5. Cases C2 and C6 (Nanoco) were supported by CASE awards, and case C4 was supported via a DTI grant.

The impact case studies reflect our impact strategy in the following ways: Institutional support via Imperial Innovations, who have formed an important role in many cases, including C2, C3 and C4. Departmental/institutional support for impact funding schemes played a role in C3 and C5.

Cases that embody our future strategic plans are C2, C4 and C5. All have arisen through multidisciplinary collaborations (within Imperial and with other institutions) and showcase the possibilities that can arise from internal and external collaborations, which will continue to be strengthened and fostered.