Institution: University of Reading

Unit of Assessment: 8 Chemistry

a. Context

During the REF assessment period, the research structure of the Chemistry Department was reorganised to replace the traditional Inorganic, Organic, and Physical sections by three thematic research groups: (i) Molecular Chemistry, (ii) Materials Chemistry and (iii) Chemistry for Life and the Environment. This reorganisation recognises that future research pathways in the UK are likely to be more multidisciplinary and applied in context, and so aims to build synergies and complementarities of expertise between staff. The new research groups are designed to be flexible enough to evolve and develop as new staff appointments are made. They will also be able to align more readily with new strategic research areas identified for support by the University (these have recently included climate change, food security and healthy ageing). The Chemical Analysis Facility (CAF) – a £4.5M, state-of-the-art analytical instrument platform established by the University in 2009, to support research in Chemistry and allied subjects – provides essential underpinning to the three research groups. See: http://www.reading.ac.uk/caf/caf-home.aspx.

By the very nature of Chemistry, interactions with industry are an important route to impact from research carried out within the UoA, and indeed key beneficiaries of our work include major companies and research organisations in the areas of (i) materials and polymers (e.g. AkzoNobel, DuPont-Teijin Films, Cytec), (ii) pharmaceuticals (e.g. GlaxoSmithKline, AstraZeneca), (iii) agrochemicals (e.g. Syngenta), (iv) fuel cells and catalysis (e.g. Johnson Matthey), and (v) nuclear chemistry (e.g. the UK National Nuclear Laboratory and the French Atomic Energy Commission).

b. Approach to impact

Our approach to impact is based on three underlying principles: i) that close relationships between universities and industries/National Facilities are required to sustain the intellectual and economic drivers that underpin discovery science; ii) that collaborative partnerships can provide successful research pathways to impact, especially where no single research-based university can provide the full breadth of chemistry-research or facilities required; and iii) that successful impact requires active support and management of the science by professional research and enterprise teams. **Interaction with industry**, in many diverse forms, is a strong driver for research activity within Chemistry at Reading, and its benefits flow in both directions. For example, the new CAF facilities not only enhance (massively) the internal research environment in Chemistry, but they are also in demand by industrial clients, so impacting on the viability of science-based UK companies. The UoA has made significant impact with local SMEs over the past 6 years through Reading's leading expertise in Knowledge Transfer Partnerships (Davis, Hayes, McKendrick x 2 – see case study). Links with industry are mainly formalised through industrial funding of PhD students, with around 40% of our research students being industrially funded at any one time. Companies with such links during the assessment period include AstraZeneca, Unilever, BioInteractions, CEMAS, Cytec UK, Dextra Laboratories, Domino, AWE, Eli Lilley, Dow Corning, DuPont-Teijin Films, GSK, Hofmann la Roche, Johnson Matthey, ICI-National Starch, Smith Detection and Xenova. Other industrial interactions include provision by Chemistry staff of continuing professional development (CPD) courses to GSK and Syngenta; (Harwood, Russell, Hayes) and involvement of industrial scientists in the delivery of undergraduate courses on industrial chemistry (GSK, Unilever, BP, AWE). Industrialists also consult for the Department on research activity, teaching development, and skills training. Furthermore these external consultants assist as award judges on annual Departmental Research Days, when graduate students present their work. The Department can thus call upon external advice from recognised experts when developing research and enterprise strategies. To cement these external interactions, Industrial Visiting Professors and Visiting Fellows have been appointed in Chemistry: currently: Thornthwaite (Unilever) and Permogorov (Johnson Matthey).

Interactions with external research groups and facilities are at the heart of the Department's research and impact strategies. With the ever increasing emphasis on multidisciplinarity in research, Reading chemists have been active in establishing interactions with research groups at other universities in the UK, Europe and beyond (including Manchester, UCL, Lancaster, Strathclyde, Aarhus, Amsterdam, Copenhagen, Lund, Münster, Strasbourg, Guiangzhou). Additionally, strong links have been built with key research enterprises and Facilities including:

Diamond and ISIS, both at Harwell; the ESRF and ILL in Grenoble; the UK National Nuclear Laboratory, Sellafield; the US National Nuclear Laboratory, Idaho; and the French Commisariat à l'Énergie Atomique. As a result, the work carried out at Reading has both national and international reach and significance. The Director of Diamond (Prof. Materlik) has held a Visiting Chair in Chemistry throughout the assessment period, and members of the Department (Hamley and Held) hold jointly-funded posts with Diamond, informing and impacting on the development of that facility. Held, for example, currently leads the team at Diamond designing and building the new beamline VERSOX – a soft-X-ray facility for surface science, atmospheric science, and catalysis research. Work carried out at Reading also informs and directs research in other institutions, both in the UK and internationally (e.g. nuclear ligands synthesised at Reading are being evaluated at Manchester, Karlsruhe, Prague, Oak Ridge National Laboratory and Idaho National Laboratory).

Chemistry at Reading has a strong history of effective and impactful collaborations with other UK and European establishments through EU funded framework-consortia (Harwood, Hudson, Davis, Held). Intellectual property generated within the Framework 7 ACSEPT and SACSESS projects (http://www.acsept.org/) has led to the development, at Reading, of a molecule that is now the European reference ligand for actinide/lanthanide partitioning in reprocessing high-level radioactive waste from future nuclear power stations (see case study). Active collaboration with the University's Research and Enterprise Service (RES) has resulted in the licensing of the IP developed within this project to the UK company TechnoComm (http://www.technocomm.co.uk/), which sells ligands for separating the elements in nuclear waste both to the nuclear industry and to researchers worldwide. Evidence of the impact of this work comes from the small but growing income stream to the University and the inventors. This work is now informing and directing attitudes towards nuclear partitioning and transmutation on both sides of the Atlantic, as it promises a technology than can deliver a hugely diminished international legacy of nuclear waste.

A variety of internal mechanisms foster and actively support a research impact culture. All staff are actively mentored, with clear line-management: the Group Heads (Colquhoun, Hamley, Hartl) carry out annual development review meetings with Chemistry staff, including research staff, where achievements are assessed, realistic targets agreed and continuing professional development needs identified. Given the growing emphasis on high-impact research, these meetings are used to identify the aspects of research programmes that will be most likely to have societal or economic impact. Actions are forwarded to the Departmental Director of Research and Enterprise (DDRE), and thence to the Head of Department and the Head of School.

Key enterprise activities of Chemistry staff include the management of industrial interactions, protection of intellectual property, providing and advice and assistance with developing technology, licensing of intellectual property and setting up spin-out companies. The DDRE (currently Harwood), is expressly tasked with disseminating information on good practice in research and enterprise, on training opportunities, and on news relating to science and industry. A designated representative (Smith) of the University's Research and Enterprise Service holds weekly meetings with members of staff in the Department to review grant applications and future plans. She also attends the quarterly Departmental Research Committee (Harwood, Chippindale, Colquhoun, Hamley, Hartl, Powell). Through RES, the Department has licensed its IP in a novel protein-synthesis methodology ("general chemical ligation") to a spinout company, TechnoPep (http://www.technopep.co.uk/). The University has actively supported maintenance of the IP in the early stages of company development, and has enabled Harwood to dedicate 21 days per annum to his role as Chief Scientific Officer of the company. This has involved the establishment of milestone achievements with a major industrial company and the signing of contract agreements with three SMEs: TechnoPep thus funds collaborations with *Creative Chemistry* (http://home.btconnect.com/creativechemistry/), *Peptide Protein Research* (http://www.peptidesynthetics.co.uk/index.php) and *SpheriTech* (http://www.spheritech.com/) with the aim of bringing the technology to market before the end of 2014. The Department has also recently obtained RES support in the development of nanowire coatings through templated electrodeposition (Squires, Elliott) (http://www.engadget.com/2012/12/22/nature-inspired-nanomaterial-better-electrode/). Colquhoun's work with DuPont-Teijin Films to develop new high-temperature polyesters for sustainable energy applications (photovoltaic support films) was recognised by his receiving the Royal Society *Brian Mercer Feasibility Award* in 2013.

As well as the work outlined above, which focuses on impact with industry and business, the Department strongly encourages **public outreach activities**. Through a targeted scheme overseen by Page, the Department annually welcomes over 1,000 visitors per annum to a variety of outreach events such as spectroscopy masterclasses for A-level students. A major attraction is the Chemical Analysis Facility through which much of the research impact of the Department is showcased. Research impact deriving from Reading research is disseminated in activities tailored to the national curriculum for school pupils and to the general public (solar cells, spectroscopy, polymers and materials). Staff have delivered a range of Public Lectures (Almond, Harwood, Colquhoun – webcast at http://www.thereaction.net/explore/our-light-materials/). The Department has used significant funding from the RSC (Chemistry for our Future), the HEA and the national HE STEM programme to support schools outreach activities (Page).

c. Strategy and plans

- The detailed structure of three Research Sections (**Molecular Chemistry**, **Materials Chemistry**, **Chemistry for Life and the Environment**) will remain under review to ensure it adapts to future changes in personnel and in the strategic areas available for impact.
- **New staff appointments will continue to be aligned with strategic research areas** identified at international, national, and University level, to maximise the impact of research.
- The Director of Research and Enterprise will continue to ensure that all research staff, but particularly early career researchers, are in a highly **research supportive environment**.
- The HoD, DDRE and HoS have been tasked with **increasing awareness of recent examples of effective pathways to impact** from Chemistry and from other parts of the University. They will, in addition, encourage colleagues to **gain advice and develop skills in the use of conventional and social media opportunities for impact**, through the University's Marketing and Communication Office and Staff Development Unit.
- The University and the Department will continue to support the exploitation of research through such proven mechanisms as partial **secondments** (e.g. Harwood) to enable further development and commercialisation of new technologies.
- Likewise, the University and the Department will continue to **support formal links with key research facilities** for mutual research and impact benefit; for example, Hamley's Diamond Professorship of Physical Chemistry and Held's Diamond Fellowship will ensure that Reading's voice continues to be influential at this important facility.
- **Collaborations** have been set up with the School of Biological Sciences and the Reading School of Pharmacy to help align Chemistry strengths with strategic research areas within the University – e.g. the Institute of Cardiovascular and Medical Research.
- Since external support for single investigators is diminishing in favour of large collaborative projects, **external collaborations will continue to be developed and new partnerships actively sought,** building on the success and learning of established collaborations.

d. Relationship to case studies

Collagen-Stimulating Lipopeptides for Cosmetic Applications (Forme Labs/P&G - Hamley)
This case study brings out clearly the benefits of a strategy that encourages collaboration with both major international companies (P&G) and SMEs (Forme Laboratories), and the effectiveness of strategic collaboration between Chemistry, Pharmacy and Biological Sciences at Reading.

Commercialisation of the Coated Stent Technology *Adapt*™ (Biointeractions - Mckendrick)
The technology was designed and developed within the framework of two successive KTP packages, with the assistance of the University KTP Centre within RES, which also dealt with the protection of the intellectual property.

Licensing of Selective Ligand Chemistry (ACSEPT/TechnoComm - Harwood)
Key enabling technology was developed at Reading within the ACSEPT project, making practical large scale production of ligands for nuclear reprocessing possible. Protection of the IP and the licensing of IP to TechnoComm were managed by RES. Harwood advises the company on synthetic strategy and on outsourcing large-scale ligand synthesis. He is involved in interactions with nuclear industry worldwide (CEA Marcoule, NNL Sellafield, US National Nuclear Laboratory Idaho). The technology is also now being developed for land decontamination, post-Fukushima.