Institution: University of Warwick

Unit of Assessment: 8 Chemistry

a. Context

Our impacts relate to the economy, society, health and the environment, and our six research themes have impact in the following areas: *Analytical Science & Instrumentation* - instruments & sensors, biomedical & diagnostics; *Chemical Biology* - drug discovery & human health, food production, biotechnology; *Interfaces & Materials* - nanotechnology, energy, semiconductors; *Polymer Chemistry* - materials, additives, healthcare; *Synthesis & Catalysis* - pharmaceuticals, fine and sustainable chemicals; *Theory & Simulation* - predicting & designing for energy, healthcare and manufacture. We create impact: directly with established business & industry; by exploitation of inventions through spin-out and licencing; by research-based outreach and public engagement.

b. Approach to impact

Our strategic approach to impact has led to a four-fold increase in annual industry research income totalling £5.07M in the period, working with more than 60 businesses. We started 85 industry-sponsored PhD projects since Oct 2008. An innovative secondment programme (17 participants, 13 companies) and a flagship regional industry-centred equipment investment (£3.8M) have created a step-change in engagement and helped to foster the spin-out companies a2sp/Tangent, Warwick Effect Polymers and Molecular Solar. Warwick catalysts and analytical methodology had substantial impact worldwide. We are inventors on 62 new patent applications. Academic staff and many researchers are involved in outreach activities engaging thousands of individuals, making important and measureable differences to young lives locally, nationally and internationally.

1. Partnerships with Established Businesses

We have developed a range of effective mechanisms to create and nurture relationships with businesses. This has created the main route to impact for our research, contributed to our strategy in terms of appointments and investments, and provided a ready market for our most important product – excellent people. Industrial income has increased more than four-fold over the period (REF4b) with a total of £5.07M raised from more than 60 businesses by 78% of our submitted staff. **Industrial collaboration is thus embedded in our research culture**. A number of Chemistry's key partners now also work with research groups across the Faculty of Science. Umbrella agreements, common contract protocols and a single academic point of contact make such a deepening of relationships easier for our partners. Our Corporate Relations Unit provides business engagement support, particularly in Warwick's Global Research Priority (GRP) areas, specifically Energy, Materials, Healthcare and Food security.

Collaborations with businesses and other organisations have led to extensive impacts and REF3b case studies: Johnson Matthey commercialised (2009) a range of catalysts developed by Wills which are now used worldwide for the large scale production of optically pure intermediates; Fox developed an anti-inflammatory drug with Funxional Therapeutics Ltd, underpinning Phase I and II trials (2009-10) and a major return for investors (2012); Barrow's petroleomic fingerprinting helped underpin a new market in analytical equipment, shapes Canadian government policy and enables their environment agency to monitor the impact of the oil sands industry (2010-), and provides strategic information to oil companies worldwide about crude oil compositions (2009-).

Extensive knowledge transfer activities have led to unusually high levels of people-movement, i.e. the migration of originators and exploiters of research between Warwick and industry. **ChemD** was the first UK industrial doctorate centre in UK Chemistry. Funded by EPSRC (2004-13) and based on the EngD model it has enabled (2008-) 30 PhDs and 16 Chemistry academics to work on projects between 21 UK companies across all major sectors. Projects are driven by strategic industry needs and commonly rely on industry background IP. This engagement inspired the creation of **Warwick Collaborative Postgraduate Research Scholarships** (WCPRS, 2008-) which operates a similar co-funding model. Through these programmes, plus traditional CASE, we have started a total of 85 industrial PhD projects since Oct 2008. Outcomes have been extensive: e.g. with Infineum UK a ChemD project led to a further five studentships and 4 y PDRA funding (Scott, Dove) leading to 2 patents and collaborations in petroleomics and polymer processing; Kurt J Lesker and Asylum ChemD projects led to a £2.1M TSB collaborative R&D grant and partnerships in Jones' SuperGen and Platform EPSRC grants, underpinning the creation

of the spin-out Molecular Solar Ltd; Bugg developed new peptides now used by Mologic to raise antibodies for an assay for MRSA; with Dioptica Scientific, RodgerA developed circular dichroism (CD) methodologies now adopted by MScan Ltd and Avacta; Element6 worked with Macpherson & Unwin on diamond electrodes leading to 8 y of PDRA funding, 7 joint patents and routes to impact with the Environment Agency, BAE Systems, AstraZeneca and BP; ChemD projects were the seedcorn for a new 10 y Framework Agreement establishing a Syngenta University Innovation Centre in Polymer Design & Action (Bon, Haddleton, Unwin).

Warwick Knowledge Transfer Secondments (WKTS, 2009-12) was led from Chemistry with EPSRC and industry funding (~£1M) to support: (i) secondments of RAs to commercial organisations to take their knowledge to application; and (ii) hosting an employee of a user organisation to conduct collaborative research at Warwick. Chemistry exchanged 17 researchers with 12 UK companies involving 11 academic groups. These secondments have quickly led to a wide range of impacts. Walton developed oxides for fuel cell catalyst applications with Johnson Matthey leading to a patent, scale-up and ongoing commercial assessment. With JascoUK, RodgerA and Scott developed a commercial standard for CD. Sadler and ICT Biosciences developed anticancer compounds and were awarded an ERC Proof-of-Concept grant for preclinical research. Dove's work with Critical Pharmaceuticals led to an RS Industrial Fellowship. Haddleton developed drug-targeting polymers with WEP that are in trials with two multinational pharmaceutical companies. Scott's secondee took Ziegler catalysis to Infineum, built a reactor, transferred know-how and developed fuel additive candidates for scale-up and manufacture. Macpherson's secondee commercialised Warwick's graphene and CNT synthesis technology with Moorfield as their nanoCVD instrument range.

The Science City Research Alliance (SCRA, 2008-) is a flagship collaboration between the Universities of Warwick and Birmingham which has enhanced our connectivity with local enterprises in the fields of Advanced Materials, Energy Futures and Translational Medicine. With support from Advantage West Midlands and the European Regional Development Fund it provided £58M of investment in state-of-the-art equipment across STEMM with the objectives of assisting businesses in their research, development and analysis functions and providing training and employment opportunities in the region. Warwick Chemistry has a key role in the Materials and Energy projects hosting £3.8M of new equipment and three 5-year research fellows. Through this scheme's business development managers we have worked with 22 regional companies.

2. Spin-outs and Licensing of Technology

The Department works closely with Warwick's technology transfer arm, **Warwick Ventures Ltd** (WVL), which provides expertise and practical assistance with: identification of potential for exploitation; funding from strategic grants; Proof of Concept funds; negotiations with angel and VC investors; protecting ideas through patents, copyright and trademarks; market research; discovering and negotiating partnerships and licensing. A total of 62 patents have been filed from Chemistry (including 26 joint with industry) with four licenses granted since 2008. The **University of Warwick Science Park** (UWSP) and WVL have provided a range of professional business support structures for **spin-out activities** including the following:

Warwick Analytical Service Ltd grew from Chemistry into a joint venture with Exeter Analytical Ltd (2002-) and has its European HQ on the UWSP. **Dioptica Scientific Ltd** (2004-) has sold Warwick's market-leading Linear Dichroism cells in 12 countries, as highlighted in publications by the BBSRC. The spin-out **a2sp Ltd** exploits Magic Tag, a Warwick biopanning technology, and operates (2008-) as **Tangent Reprofiling Ltd**, providing the chemical biology division of the SEEK group. A joint venture with a publically listed healthcare company will take a Magic Tag-discovered cancer lead through clinical trials. **Warwick Effect Polymers Ltd** (2001-) developed a suite of technologies in controlled polymerization, principally for polymer therapeutics and nanomedicine, and now forms a key part of the Polytherics group (2012 - see 3b case study). **Molecular Solar Ltd** (2008-) is commercialising Warwick chemistry patented 3rd generation solar cell technology with private equity funding and collaborative TSB grants, and received a Lord Stafford Award for *Innovation in Development* (2011).

Uniscan launched a new Scanning Electrochemical Microscopy (SECM) instrument (M470) in 2013 that exploits Unwin's patented Intermittent Contact SECM. Future instruments will exploit a new license on Hopping Mode Intermittent Contact SECM and a new scanning droplet technique. Gibson and Bon have an option agreement and substantial research contract with a multinational chemical company to exploit their patented crystallisation inhibitor technology for tissue samples.

3. Outreach & Public Engagement with Research

Chemistry is a flagship Warwick department in outreach and we consider ourselves to be amongst the leaders in the UK. **Nationally**, Sadler is chair of the RS Summer Science Exhibition committee and we work with Bristol, Southampton and the RSC through the Science Education & Industry Board of which Nick Barker – our permanent **outreach officer** since 2008 – is a Member. Activities are principally research-based and often *underpinned* by specific projects. Almost all academic staff are involved and we have engaged ~7000 people p.a. In 2012/13, 796 young visitors worked in our labs and 7308 attended demonstrations. As part of a large programme with The Grange – a unit for children with behavioural problems – the Unwin and Macpherson groups supervised preparation of diamond electrodes and the use of this Warwick technology to analyse soil samples from a local car factory. As a result of this direct engagement with research, the children showed markedly improved behaviour and motivation (teacher feedback); Grange pupils who work with us are 62% more likely to return to mainstream schools than the control group. Other examples of outreach include: Macpherson's 2011 Daniel Lecture was seen by 300 schoolchildren; Notman's living cell simulation was explored by 300 visitors at Birmingham's *ThinkTank* (2011).

Internationally, we work with the Gateway for Gifted Youth and Warwick in Africa, with staff visits to Botswana, South Africa and Ghana. Stavros's three 1-week school tours in Athens, Georgia (EPSRC/NSF, 2010-12) were cited as best practice by the NSF programme director.

We work with Warwick's Communications Office to inform the wider public of our research via a large number of media campaigns. Bon's research on fruit juice in chocolate was reported by worldwide media (2013); Costantini, Fox and Scott's Olympicene (2012) project was a Top 5 BBC story; Bugg's work with Biome Bioplastics (2013) was covered by several BBC TV channels.

We also target a scientifically literate public. *When Worlds Colloid* (Bon's TedXWarwick talk) received >15,000 YouTube hits. Other projects include Unwin's *Electrochemistry of Surfaces*, Sadler's *Metals in Medicine* and Clark's *Cars on Mars*. Bugg contributed to *The New Optimists*, a popular science book and British Association festival session. Challis created podcasts for *Nature Chem.* (2008) and contributed to BBC *Science in Action* (2009); O'Reilly was interviewed by *Nature* for a Turning Point Feature (2012) and by Andrew Marr (BBC R4, Start the Week, 2012).

c. Strategy and plans

The REF2014 period has seen a step-change in all aspects of our impact activity. Going foward we will continue the mechanisms described above, refining them on the basis of our experiences and successes, and we will create **new incentives and support processes** as described below.

Warwick grants 50% of net proceeds of commercialisation to the academic inventor. Further motivation will come from emphasising impact in academic role descriptions, assessing impact in annual review and promotion, and prioritizing study leave specifically for impact activities.

The mechanisms of collaboration and equipment utilization that we have established through SCRA will continue via the new Warwick Scientific Services; in a trial project (2011) 30 clients were attracted to a specialist analytical services operation in chemistry. The pioneering chemistry WKTS scheme has informed the running of Warwick's EPSRC Impact Acceleration Account (2013-); new projects under this scheme and HEIF funding involve e.g. nanocomposites, optoelectronics and synthesis. Our Polymer Club network of 60 member companies demonstrates a successful model for business engagement, and we will develop this in other areas of strength. Our body of Honorary/Visiting Fellows (16) and Professors (5) from industry will perform more strategic advisory and collaborative roles, e.g.: Hon Prof Allyson Reed (ex TSB) advises on business engagement; Prof Ken Lewtas (Infineum, RSC Creativity in Industry Prize 2013) is involved in several new projects; Dr Robin Bannister (Biocopea) developed a renewables-based drug delivery system with Clark that culminated in a £25 million investment for a new company infirst^{+}.

Exciting new impact case studies will be recorded e.g. from spin-outs Molecular Solar and a2sp/Tangent, with collaborating companies BASF, Cadbury, Element6, Infineum, infirst^{+}, Jasco, Johnson Matthey, Kraft, Moorfield and Uniscan. These will be assessed during staff annual review and form a key part of departmental strategic plans so that appropriate support and resources (e.g. study leave, Impact Acceleration Account and university funding, WVL support) can be provided.

d. Relationship to case studies

The mechanisms described above have been widely used in our case studies. *Warwick Effect Polymers* was nurtured by WVL, resides on the UWSP and benefitted from all collaborative programmes. *An anti-inflammatory molecule* and *Wills Catalysts* have used WVL, access to SCRA facilities and secondment/studentship support.