Institution: University of Leeds

Unit of Assessment: Chemistry (UoA 8)

a. Context

The UoA exploits many approaches to translate high quality research and knowledge into economic and societal benefit, and is fully supported by Leeds' integrated Research and Innovation Services Unit. Each of the UoA's research groups (APC: Atmospheric & Planetary Chemistry; CBMC: Chemical Biology & Medicinal Chemistry; CCCP: Computational Chemistry & Chemical Physics; CDA: Crystallisation & Directed Assembly; CPS: Colour & Polymer Science; PRD: Process Research and Development) is explicitly linked to specific beneficiary/user sectors that include the pharmaceutical (CBMC, PRD), biopharmaceutical (CBMC, CDA), agrochemical (PRD), healthcare (CDA), medical biotechnology (CDA), fine chemical (PRD, CPS), energy (APC, CCCP, PRD) and water (CDA) sectors and governments (APC) (see Table, Section b). A primary function of key staff is to translate and exploit groups' research in the following strategic areas: medicinal chemistry (CBMC), colour science (CPS) and process chemistry (PRD). The realisation of impact from the groups' research is driven by the University's HEIF-funded innovation "hubs" that each focus on specific, strategic external sectors; these formalised "hubs" align externally-recognised research strengths with external need, facilitate strategic engagement and partnership with end-users, and deliver clear impact and innovation pathways that maximise the impact of the UoA's excellent research. Thus, the UoA's integrated and strategic approach has yielded many types of impact including:

- Economic impacts realised through spin-out companies or licensing;
- Translation of biomedical research to yield drug candidates and marketed products;
- Removal of barriers to innovation e.g. through collaboration with industrial partners; and
- Effective policies informed by expert advice and tools that are exploited by end-users.

b. Approach to impact

The UoA's groups have explicitly mapped their activities onto external beneficiaries (Table), and are supported by the University's sector-facing "hubs" to generate impact from their research. Based on the specific needs of external sectors, tailored delivery plans are delivered by these hubs through activities that may include: engagement (as appropriate) with industry, clinicians and government; assistance with developing robust pathways to impact; engagement with specialist consultants; and proof-of-concept projects with definite impact objectives. The delivery plans are facilitated by professional Innovation Managers (IMs) who support academics to secure funding streams and external partners; assist shaping proposals to ensure that end user needs are addressed; and, post award, monitor progress against specific milestones. The IMs facilitate access to the University's Impact Acceleration Account funding (*ca.* £5M; EPSRC, HEIF) e.g. to fund proof-of-market/concept activities, secondments and strategic partnership development. In addition, the Digital Print Centre of Industrial Collaboration (lead: **Lin**; founded through Yorkshire Forward £600K grant) is a "one stop shop" between academia and industry, and has assisted the successful brokerage of R&D contracts totalling >£2M since its inception in 2005. The Institute for Process Research and Development (iPRD) hosts an industry club, and with its two senior ex-industrial staff (Muller, returned under UoA12, and **Blacker**), helps drive collaboration with industry e.g. on scale-up studies that exploit its pilot plant facilities funded (£4.5M) by ERDF and Yorkshire Forward. **LA Nelson** received the 2008 Royal Society Brian Mercer Prize for Innovation.

Table: Alignment with external sectors. Engagement by many (√√) and some staff (√) is indicated.

Sector Hub ↓ / **Group →**	CBMC	APC	CCCP	CDA	PRD	CPS	**Beneficiary / user sectors**
Pharm & biopharmaceutical	√√			√	√		Pharmaceutical and biopharmaceutical
Stratified Medicine	√						
Medical Technologies				√			Healthcare & medical biotechnology
Climate & Geohazards		√√					National governments
Energy		√	√		√		Energy
Water				√			Water
High-value chemicals	√			√	√√	√√	Pharma, agrochemical, fine chemical

In specific areas of strength, UoA staff can access additional resources to aid translation. The

Medical Technologies Innovation & Knowledge Centre (£10M; EPSRC, BBSRC and TSB) provides innovation infrastructure and proof-of-concept funding to progress new technologies and to secure commercial investment (e.g. see Impact case study 1; **Aggeli**). Investment in Leeds's Biomedical & Health Centre (BHRC) has provided infrastructure for translational biomedical research including 16 Senior Translational Research Fellows (**Bon** and **Beales** in the UoA) and technology groups (including the Medicinal Chemistry & Chemical Biology, MCCB, group; group leader **Foster** plus research staff in the UoA). Proof-of-concept investment allocated by BHRC to the MCCB group was complemented by translational funding provided by a Wellcome Trust Institutional Strategic Support Fund Award (£270K matched by University Funds). The Clothworkers' Innovation Fund (£410K investment by the Worshipful Company of Clothworkers of London matched by the University) has also encouraged innovation and accelerated commercialisation.

The UoA has capitalised on Leeds' pioneering approach to intellectual property commercialisation as the first UK University to outsource its technology commercialisation activities (to Techtran, acquired by IP Group PLC in 2005). IMs support academic staff to file initial opportunity disclosures with Leeds's integrated Research and Innovation Services Unit, and then work with the dedicated commercialisation team to protect and manage IP, to facilitate interactions with IP Group PLC and to define robust commercialisation mechanisms.

Direct exploitation of intellectual property

Many approaches are used to exploit intellectual property generated within the UoA, e.g.:

- Six operating companies (three selected examples below plus *Keymodule, Keracol and Inovink*) were founded by Chemistry staff, four of which were supported by IP Group investment;
  - *Photopharmica* (**Griffiths**, founded: 2001) develops photodynamic therapeutics (see Impact case study 3). It has received £11.5M investment since 2001 from IP Group and others.
  - *C-Capture* (**Rayner**, founded: 2009) develops solvents for CO_2 capture and storage. It is supported by £1.4M investment (Dept. of Energy & Climate Change Energy Entrepreneurs fund, IP Group, NE Technology Fund; University), was shortlisted for a 2012 Shell Springboard award and is a Carbon Trust Entrepreneurship Fast-track programme member.
  - *Green Chemicals* (**Lewis**, founded: 2005) develops safer chemicals for consumer and industrial applications. It has a current market capitalisation of £6.1M (Sep 2013).
- Implementation of clear licensing pathways, including:
  - *Credentis* was founded to commercialise peptide gels developed by **Aggeli** through a license covering applications in dental care. Its first two products – Curodont™ Repair and Protect, the first of their kind in dental care – were launched in 2013 (see Impact case study 1).
  - Leading dye manufacturers have engaged with Leeds with a view to jointly licensing the novel salt- and alkali-free reactive dyeing technology developed by **He** and **Lin**. It is hoped that long-term licensing deals will ensure continuing commercialisation activities; to date, £400K has been received from one potential licensee.
  - *Yorkshire Process Technology* undertakes contract pharmaceutical research. It exploits transition metal-catalysed processes including CATHy-based catalysts developed by **Blacker**.
  - *Albany Molecular Research Inc.* is commercialising lead-like scaffolds by exploiting synthetic approaches developed by **AS Nelson** and **Marsden**.
- Integration of tools into commercial products. **Shalashilin**'s new Ehrenfest approach to computational molecular dynamics is being included in the *MOLPRO* quantum chemistry suite.

Collaborative research with industrial partners

A wide range of mechanisms has been exploited to collaborate with companies to align pre-competitive research to industrial need, for example:

- Collaborative grants with industrial partners, to ensure close alignment with future need and a clear pathway to impact. Selected examples include:
  - A £3M grant fully funded by the state Chinese company Sinochem was secured by **Lin**, and integrates projects in colour, semiconductor, polymer and plant sciences.
  - The €196M European Lead Factory funded by the Innovative Medicines Initiative generates leads for innovative therapeutic mechanisms (Leeds share: ~€2M; **Nelson**, **Marsden**, **Foster**). It is led by Bayer and involves 6 other pharmaceutical companies and 10 SMEs.
  - The €26M CHEM21 consortium (Innovative Medicines Initiative) develops sustainable methods for pharmaceutical synthesis (Leeds share: ~€1.5M; **Blacker**, **Marsden**, **Rayner**,

Johnson, **AS Nelson**). It involves GSK, Orion, Sanofi-Aventis, Johnson & Johnson and Bayer.

- Collaboration with companies to remove barriers to innovation. For example, eight TSB grants have supported supply chains in diverse areas such as cosmetics, medical diagnostics, organic electronics, process chemistry, pharmaceutical delivery and double glazing. In three cases, companies founded by Chemistry staff have been partners on these grants.
- >60 collaborative PhD students (including fully-funded and industrial CASE awards) in post since January 2008 with partners including Avecia, AstraZeneca, BP, Chesapeake, Coats, Dyecat, Eli Lilly, Essilor, GSK, Heinz, Huntsman, ICI, Infinium, Medimmune, Novartis, Pall Membranes, Paratech, Pfizer, Piramal, Prolysis, Symbiosys, Syngenta, Unilever and Valspar.

Provision of expert advice to inform policy development

Outstanding atmospheric chemistry research in the UoA has informed policy development:

- The *Master Chemical Mechanism* (**Pilling**) is exploited to predict the impact of volatile organics on air quality and to inform policy development in EU, Asia and US (see Impact case study 4)
- **Pilling** was Chair of the Air Quality Expert Group (2002-2009) that produced five major reports that influenced Defra. He also chaired the modelling group assessing methods to determine the likely impact of a third runway for Heathrow, and was a member of the Royal Society group that produced a science policy report (2008) on ground-level ozone levels in the 21st century.

c. Strategy and plans

The UoA's ongoing strategy and plans to maximise the impact from its research include:

- Explicit mapping of groups' strengths onto external sectors (Table, Section b). The UoA's staff provide ongoing leadership in the Pharmaceutical & Biopharmaceutical (**AS Nelson** [Director] and **Wilson**) and High-value Chemicals (**Blacker**, **Marsden**) hubs. Leeds allocates ~70% HEIF funding (£2.7M pa in 2011-15) to hubs, with the remainder deployed within faculties to complement that investment.
- Sustained leadership within national academic-industry networks e.g. the EPSRC-funded "Dial-a-Molecule" (**Marsden**: co-I and Catalysis theme lead; PRD group) and RCUK-funded "PPI-net" (focusing on protein-protein interactions) (**Wilson:** co-Director; CBMC group) networks;
- Ongoing support for staff to drive industrial engagement (e.g. **Marsden**: Royal Society Industrial Fellowship, Reaxa and Piramal) and exploitation (e.g. 3 Yorkshire Enterprise Fellowships).
- Policies to encourage staff to drive translational activities and to undertake up to 35 days' consultancy per year. These policies have been enabled staff to commit the necessary time to the spin-out companies that they have founded.
- Provision of space and facilities access to companies in which the University has a stake (e.g. C-Capture, Keracol, Yorkshire Process Technology).
- Sustained investment in BHRC's MCCB group that housed within Chemistry. The group's leader (**Foster**) and research staff are supported to focus on translational biomedical research e.g. in the cardiovascular (via Leeds's Multidisciplinary Cardiovascular Research Centre) and cancer (via Leeds's Cancer Research UK Centre) therapeutic areas.
- Embedded industrial engagement in interdisciplinary research centres, for example:
  - The Institute for Process Research and Development (iPRD) industry club that currently has 15 member companies from Europe, India and China;
  - The Astbury Centre's programme to develop sustained interactions with industry is supported by an advisory board comprising 18 senior industrialists.

d. Relationship to case studies

Each case study was underpinned by the UoA's research groups that have been supported through strategic investment in staff and facilities (see REF5 document). Each case study displays hallmarks of the UoA's strategic approach to supporting impact and innovation. The development of a new class of products for treating early stage dental decay (Impact case study 1) exploits self-assembled peptides (a key theme of the CDA group) and was supported through Leeds's £10M Medical Technologies Innovation and Knowledge Centre. Lhasa Ltd. was housed within Chemistry for over 30 years (Impact case study 2) and exploited underpinning research at the interface with biology (now driven by the CBMC group). Photopharmica, founded to develop novel photodynamic therapeutics, also aligns with the CBMC group and received £11.5M investment coordinated by IP Group PLC (Impact case study 3). The *Master Chemical Mechanism* was developed by the APC group that has received sustained strategic investment in staff and facilities (Impact case study 4).