Institution: Durham University

Unit of Assessment: 8

a. Overview

Durham University's collegiate system accommodates 15000 students (including 1900 international students from 120 countries; 3500 postgraduates) and employs over 3000 staff. Durham Chemistry is one of 7 departments within the University's Science Faculty and is a thriving centre for both research and education. Its research activities lie within UOA 8. We have an academic staff comprised of 19 Professors, 7 Readers, 9 Senior Lecturers and 6 Lecturers, with an average and median age of 45 and 44. 3 current and 3 emeritus staff are Fellows of the Royal Society. We teach around 460 fte undergraduates a combination of 4 year M.Chem (80%) and 3 year BSc courses as well as interdisciplinary degrees under our Natural Sciences programme. Teaching within the Department follows a research-led philosophy from year 1 and is coordinated by 3 teaching sections (Inorganic, Organic and Physical). We are currently ranked 2nd or 3rd in the major undergraduate league tables (Times, Independent Good University guides). We have a long-standing and strong Departmental ethos for collaborative research. Our research is structured (see Figure 1 and Table 2) around 6 interdisciplinary Research Groupings (RGs), with each academic a primary member of one grouping. These groupings interact strongly with the University's research centres and institutes as well as strategic external partners to deliver high impact research. Durham physical science is ranked in the world top 50 (Times Higher), and is 11th in the world based on citation scores (the only UK university in the top 20). The Department is listed in the world top 50 (Shanghai Rankings) in terms of the percentage of outputs in top chemistry journals, and we have a collective h-index in REF period of over 55.

b. Research strategy

Process: The Department's research strategy aligns closely with the University's 2010-2020 strategy, which includes research-related aims of: transformative research; the highest standards of research-led education; international partnership building and sustainability. We exploit the subject-specific strengths of our 6 Research Groupings and the collaborative opportunities that arise from: a Departmental culture that has developed over the last 40 years; the close integration with other departments in the University; and our links to external strategic partners. Our strategy and its implementation is managed by:

- A 10 year research and education strategy (current 2010-2020) written/developed by Head of Department (HoD), Director of Research (DoR) and Director of Education (DoE) with input from all academic staff; this internal document aligns with Faculty and University strategies.
- Specific actions are captured in an annually-updated 5 year implementation plan, to which all (academic and support) staff are invited to contribute. It is monitored quarterly by our Management Advisory Group and Research Committee and focusses on 7 key challenges: Research Performance; Student Experience; International Standing; Financial/Infrastructure Sustainability; Partnership Building; Staff Support; Community Engagement; and Chemistry's Future.

Four main committees, which report directly to the Board of Studies, manage and monitor the research activities of the Department. The performance/activities of Research Centres and Institutes (Figure 1) are assessed annually by the Faculty Research Committee and University Research Committee, on which the Department has representation.

Table 1: Committees – *Members*	Committee Remit
Management Advisory Group (**MAG**) – *HoD, DoR, DoE, Teaching Section Heads, Senior Administrator*	Advises HoD on education and research, budgets, oversees appointments and promotions.
Research Committee (**RC**) – *DoR, HoD, RG leaders underlined in Table 2, Research Administrator*	Formulates/implements research strategy, allocates PhD funding, coordinates funding applications, awards and research leave.
Research Services Committee (**RSC**) – *Service Managers, Academic Reps*	Management and development of the analytical facilities and workshops.
Graduate Studies Committee (**GSC**) – *Chair, 3 Academics, Postgraduate Administrator)*	Manages all aspects of the recruitment, training, monitoring and welfare of graduate students

Research Structure: Within the Department we have 6 interdisciplinary Research Groupings with each PI a primary member of one grouping (Table 2) and many choosing to be secondary member of others. Several of these groupings are closely aligned with larger research Centres or Institutes as shown in Figure 1 (in Durham, Centres typically involve 2–3 departments collaborating in a specific research area; Institutes cover wider areas and involve several departments across faculties). Groupings, Centres and Institutes also interact externally with strategic industrial and Northern 8 (N8) university partners and catapult centres such as the Centre for Process Innovation (CPI). For example, our Sustainable Chemistry and Catalysis grouping unites 8 PI-led groups, is aligned with the Centre for Sustainable Chemical Processes, works closely with 10 industrial partners and represents an area of major activity of the overarching Durham Energy Institute. Our Research Groupings have been developed to implement the strategic aims of the Department over the next 10 years (see Section B). We recognise, however, that there are significant research opportunities between these groupings and we encourage a number of less formal "Research Collectives" where groups of PIs collaborate on specific project areas. One example is in the "Cement/SMC^3" project where we have around 12 PIs working collectively with a cohort of 12 PhDs and 3 PDRAs and our strategic industrial partner P&G.

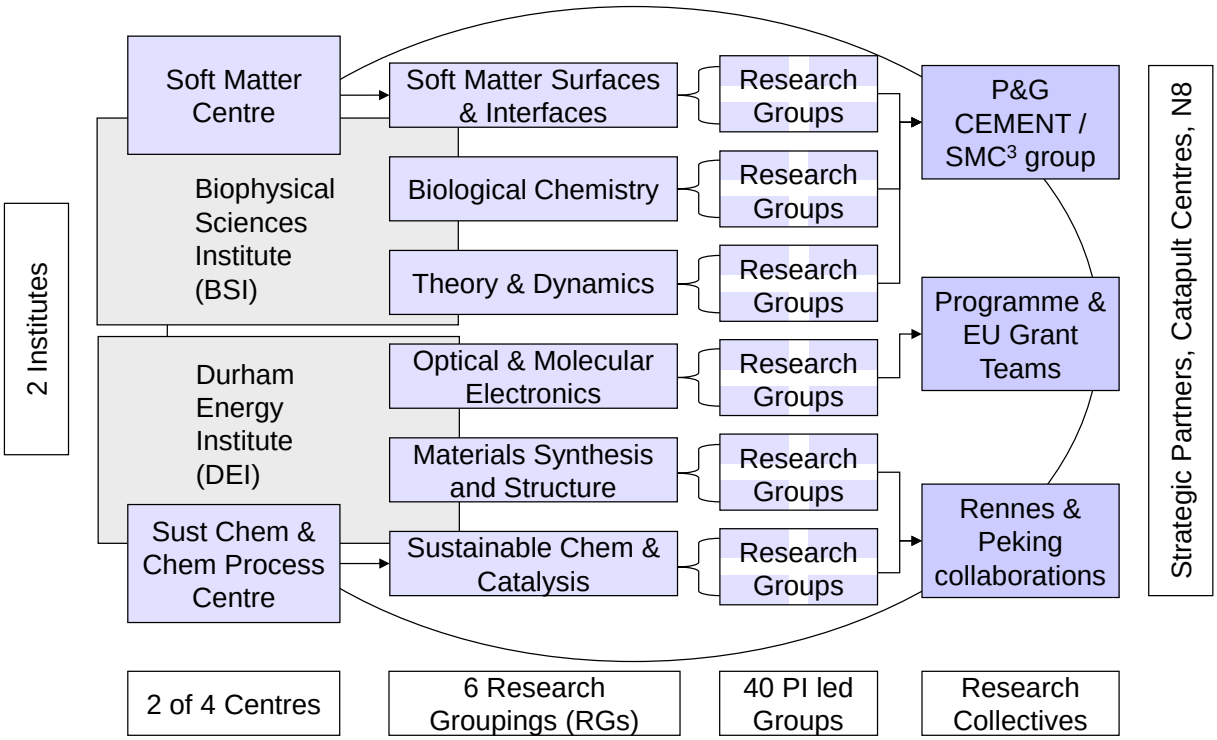


Figure 1: Research organisation at Durham; departmentally centred activities lie within the oval. Only a subset of the Centres, Institutes and Research Collectives are shown.

Strategy: Our current areas of focus and strategic aims closely follow those laid out at RAE 2008, with adjustments where staffing changes or research developments have led to new opportunities. Specific aims at RAE 2008 which have been achieved include:

- *Staffing*: The Department size is such that we choose to specialise in areas where we can lead internationally. Our strategy and recruitment policy has been to strengthen these and retain critical mass within them; appointments have been made to achieve this (Section C).
- *Research structure*: In 2009 we refreshed our internal collaborative structures into 6 more focussed Research Groupings to reflect our interdisciplinary research targets; their strategic aims and focus areas are included in Table 2. Research Groupings produce a short research plan containing their key goals every year using a standard template; plans are overseen by our Research Committee. Typical activities include collaborative research, organising network/workshop activities, working with strategic partners and organising national/international conferences. Staff typically invest around 60% of their research time on single PI projects and around 40% on collaborative work within a Research Grouping or other collaborative team. This is evidenced by around one third of 2012 publications involving more than one Durham research group. Many staff from other Departments are integral members of

our Research Groupings, but are not included in Table 2.

Tab 2: Research Groupings	RG Research Areas and Strategic Aims
Soft Matter Surfaces and Interfaces (**SMSI**) – *Hutchings, Badyal, Bain, Cameron, Cooper, Engelskirchen, Kataky, Khosravi, McLeish, Staykova Thompson (RG leader; joint appointment)*	Novel polymer synthesis, multiscale modelling, surface and interfacial modification and cutting-edge surface characterisation techniques. RG collaborates across discipline boundaries to tackle academic, industrial and societal challenges associated with: the design, modification and characterisation of functional interfaces; and understanding the correlation between molecular architecture and the physical properties of soft matter in the solution, melt and solid state.
Biological Chemistry (**BC**) – *O'Donoghue, Cameron, Cobb, Congreve, Hess, Hodgson, Kenwright, Money, Mosely, Sanderson, Steel*	Functional bionanomaterials, synthetic biology, bioinorganic chemistry, structural biology and protein ligand design. Major challenges targeted include: the construction of functional biomaterials such as virus particles; the understanding of mechanisms of localisation of specific metals to protein targets; and the design of next generation anti-microbials to combat protozoan, bacterial and viral pathogens.
Theory and Dynamics (**TD**) – *Verlet, Carty, Hutson, Miller, Tozer, Wilson, Wrede*	Development and use of the tools of quantum mechanics, laser manipulation, control and spectroscopy, and computational chemistry to understand classical and quantum dynamics, electronic structure and molecular processes. Key targets include: routes to the control and reactivity of matter at ultracold temperatures; development of new computational methodologies; and understanding the nature and dynamics of excited states and complex molecular systems.
Optical and Molecular Electronics (**OME**) – *Coleman, Beeby, Bryce, Butler, Palsson, Parker, Williams*	Research focusses on developing: new functionalised organic and organometallic systems capable of supporting and transferring electrons for lighting and memory applications; new imaging techniques for biological systems; the synthesis of reactive optical probes to detect spatial and temporal changes in cellular concentration of bioactive species; and the exploitation of nanocarbons for displays, sensing and smart packaging.
Materials Synthesis and Structure (**MSS**) – *Prassides, Aguilar Malavia, Dawn, Dracinsky, I Evans, J Evans, Hodgkinson, Howard, Pohl, Steed*	Preparation, characterisation, understanding and exploitation of materials with enhanced figures of merit for electronic, superconducting, magnetic, optical, structure, data storage and energy applications such as fuel cells. Strengths in the synthesis of materials and in the development and application of advanced structural characterisation tools including diffraction, solid-state NMR and physical property measurements.
Sustainable Chemistry and Catalysis (**SCC**) – *Whiting, Baxendale, Dyer, Fox, Hughes, Beaumont, Sandford, Walton (2014→)*	Research in the areas of direct fluorination, multi-phase reaction handling and multi-step organic synthesis in flow systems, bifunctional and asymmetric catalysis, aqueous chemistry, homogeneous and heterogenous catalysis. Major scientific challenges tackled include clean, sustainable routes for the production of feedstock chemicals from biomass and waste materials, including CO_2, and fungal/algal sources.

- *Funding*: In 2008 we realised the need to diversify our research income streams, which had traditionally come largely from research councils. We have significantly increased funding income from EU sources and industry from 11 to 30% (see Section D).
- *Partnerships*: We have placed a strong focus on developing key strategic partnerships with external bodies institution-wide to enable research collaborations. Our strategic research partnership with P&G (see Section E) has been acknowledged internationally (e.g. P&G Global Business Development University Partner of the Year, 2011; Jeff Weedman presentation to US Congress, Feb 2012; Wilson "Review of Business University Collaboration" 2012). One highlight is the Cement/SMC^3 project on surface modification. Three of our research groupings

(SMSI, MSS, BC) lead the P&G research links, though all have contributed. Our collaborative research portfolio is >£4M and we work with P&G in 7 countries. New EU support for an industrial training network (EID, €1.5M) will underpin PhD-level research until 2018.

- *Interdisciplinarity*: We have achieved our 2008 goal of embedding researchers from cognate disciplines in the Department to share expertise and research infrastructure. We co-located 7 Biology research groups in our building, bringing huge benefits to our BC research grouping; the appointment of Nigel Robinson, a world leader in metalloproteins, to a BSI chair links strongly with many research activities in Chemistry and has led to several collaborative projects; we have invested jointly with Earth Sciences in high-pressure facilities to tackle problems in both catalysis and carbon capture and storage; we share high-cost analytical facilities across the University and N8 region to maximise usage.
- *Collaborations*: We have continued to place major emphasis on best-with-best collaborations within or between departments at Durham (these have a zero activation barrier), or with external Universities, institutions or industry (where RGs/Centres are often the catalyst). Extensive examples are given in Section E, but our BC grouping have worked closely with Durham's BSI; TD are involved in major programme grants involving Durham Physics, Imperial College and groups across Europe and the world via the NE Quantum Centre; SCC link closely to the activities of the DEI; and around 50% of our publications involve international co-authors.

Based on our 2010-20 strategy document, our goals for the next five years include:

- *Partnerships*: We are building similar relationships to our P&G partnership with other blue chip companies (e.g. BAE, IBM, Akzo Nobel) and SMEs. For example, our SCC research grouping is spearheading the development of an Integrated Chemical Research Facility within the Department (£1.4M University investment 2013), where various aspects of process chemistry can be developed. The facility will be accessible to external companies and SMEs at Technology Ready levels 1–3, and we will work closely with the Centre for Process Innovation (CPI) who have facilities for further scale-up research (TR 4–6). We have made strategic investment (2012 appointment of Baxendale to a chair) to strengthen this area.
- *Doctoral training*: We plan to continue our successful model of industry-academia training of student cohorts through initiatives with industry, RCUK and EU funders. The SMSI Grouping will grow Cement/SMC^3 research with P&G in the area of soft matter and functional interfaces via an EU award of €1.5M (MICSED European Industrial Doctorate project, 2014–2018). We will launch a wider EPSRC-supported industrially-linked CDT in this area (SOFI, ~£9M total value) in 2014 jointly with Leeds and Edinburgh.
- *Future focus*: Research focus areas are given in Table 2. Specific areas we plan to grow in future years include nano-carbon chemistry where our OME Grouping have significant and strong links with companies such as BP and Shell. In the MSS Grouping area we see further growth via UK-Japan programmes in the area of molecular superconductors (e.g. EU funded programme and Durham-Rennes-Tokyo partnership), energy materials and expertise in structural science. Our BC Grouping see growth in metallomics and next-generation anti-microbials; and we will develop strength in sensing at the BC/OME boundary. We also plan a major cross-Department programme in the area of "stability" with industrial partners taking advantage of strategic appointments in soft matter across the faculty. Recent appointees in our TD grouping will work closely with Durham's new Institute of Advanced Research Computing to exploit interdisciplinary opportunities.
- *Internationalisation*: We have a multi-pronged approach to developing international partnerships. In 2014 we will welcome the first students on a research-led 2+2 integrated Masters degree programme with Peking University (top in China), which is sponsored by P&G. We have strong research links and joint degrees with key partners such as Rennes, Tokyo Institute of Technology and UWA. We also maintain close international links with our 10 (deliberately focused) Erasmus partners and institutional partners in the Matiriki network. To support internationalisation our International Coordinator manages a travel/seedcorn fund to help staff kick-start collaborative research activities.
- *Infrastructure*: We need to maintain our excellent research infrastructure and will continue to exploit the benefits of shared infrastructure with partners within the N8 (see Section D).

c. People, including:

i. Staffing strategy and staff development

Our staffing and support strategy has followed that laid out in our RAE 2008 strategic plan, which

was to invest and grow in our areas of strength.

- In 2008 the Department had undergone a period of planned expansion and replacement of a number of retiring senior staff. Our 2008–13 goal was to nurture early career staff, and embed recent senior appointments (Prassides and Bain) whilst maintaining staff numbers. This has been achieved, as evidenced by growing recognition, research income, and the development of sustainable groups by new staff. Annual research spend has grown steadily by around 40% since 2008. Our REF2014-returned cohort size is essentially the same as RAE2008.
- We have a stable staff cohort and only three members of academic staff have moved on in the REF period: Clarke to a chair in physics at his alma mater (Sheffield), Marder to a C4 inorganic chair in Würzburg and Low who has returned to his native Australia. Clarke has been replaced by Engelskirchen to maintain critical mass in the area of the SMSI research grouping; Marder's chair was used to appoint Baxendale to strengthen the SCC grouping, support our synthetic programmes and build new links with key industrial partners; Low has been replaced at the junior level by Walton, who will join in January 2014.
- Four other planned appointments have been made in the period: Miller to a senior lectureship in physical chemistry as part of a Durham strategic investment in computational science, Cobb to a lectureship in organic chemistry, Hess to a lectureship in bioinorganic chemistry, and Beaumont to a fixed term lectureship in physical chemistry. Each strengthens Research Groupings within the Department and has strong interactions with University Institutes. Each has established strong research groups and attracted RCUK and other external funding.
- A number of staff have won fellowships in the REF period: Verlet (EPSRC Advanced Research Fellow, 2006–11; ERC 2012–17); Prassides (Leverhulme Trust Senior Research Fellow, 2010; Japan Society for the Promotion of Science Fellow, 2009); Low (EPSRC Leadership Fellowship, 2009–14); Cooper (EPSRC Advanced Research Fellowship, 2006–12); Cobb (Ramsay Memorial Trust Research Fellowship, 2008–10); Dyer (Royal Society Industry Fellowship, 2011–14); Money (Royal Society URF, 2011–16); Beaumont (Leverhulme and Addison Wheeler Fellowships, 2012–2017); Cameron (OCE Fellow, Australia); Butler (Ramsey Fellow 2013–5), Parker (ERC 2011–16).
- We anticipate a relatively stable staffing profile for 2013–18, with three full-time academic retirements in period. Proleptic appointments will be made at a junior level to maintain a balanced age profile in areas of functional molecules and synthetic macromolecular chemistry.

Career Development: We have a strong commitment to staff support at all levels. Strategic actions in this area include:

- All new staff are assigned a mentor to plan career development and meet formally with the HoD at least every 6 months.
- All junior staff are required to attend the University course on training to teach. They are also encouraged to attend modules on student supervision, running research projects and a mentored programme on raising research funds. Durham has won national awards (2009 *Outstanding Support for Early Career Researchers* award from Times Higher Education) for these activities, which are also made available to PDRAs and other ECRs. Training for senior staff is assessed during our Annual Staff Reviews (ASRs) and provided as needed.
- We work closely with the University's Centre for Academic Researcher Development (CARD) to train staff in best research practice, ethics and to ensure adherence to the Concordat to Support the Career Development of Researchers. Durham is one of only 15 UK institutions with an EC HR Excellence in Research award.
- All staff have an annual review (ASR) to set goals for the upcoming year. These are all assessed by the HoD and appropriate action plans developed; follow-up occurs at various stages in-year. We have clear guidance mechanisms for academic probation and promotion in place, which are discussed in ASRs. Academic staff and independent fellows also develop/discuss Personal Research Plans (PRPs) annually with an appropriate colleague to discuss goals on current projects and ambitions/opportunities for the future.
- We support high-quality independent fellowship/ECR applicants by assigning a "Departmental Champion" to work with them. EPSRC and URF Fellows are treated as other junior academics and given support via PhD and 4th year studentships. Bain has led two bids under the COFUND scheme (€10.5m total) which fund a major University Junior Research Fellowship scheme (2010-19). We have also used COFUND to help bring talented young academics such

as Beaumont to the Department.

- We are committed to equality and diversity issues and support this via e.g. family-friendly flexible working hours. The Science Faculty has Athena Swan bronze status and the Department will apply for silver in March 2014. We have 9 female members of academic staff and a further 5 female staff on our teaching team. Our 2013 undergraduate intake is 55% female. We employ and return a profoundly deaf member of staff.
- We have an internationally diverse staff (both fixed term and permanent). Our permanent staff originate from: Belgium; Bulgaria; Germany; Greece; India; Iran; Russia; Serbia; Sweden; the UK; and the USA. Our 2012 postgraduate population intake came from 11 countries and we regularly host summer research students under the IAESTE scheme.
- We attract overseas researchers via a number of schemes including via Durham's Institute of Advanced Study (IAS) which offers a range of scholarship opportunities. e.g. the IAS sabbatical visits of O'Brien (Manchester), McBane (Grand Valley State) and Mezaros (Budapest).
- Research, teaching and other news stories are shared with staff via monthly Departmental newsletters (http://chemistry-alumni.dur.ac.uk/wiki/).

ii. Research students

The research interests and collaborative nature of the Department are such that individual research groups are small-to-medium in size; the largest group in the Department has typically been ~15 members. Despite a relatively low number of institutionally supported students (in RAE2008 and REF2014) and funding changes, we have grown the number of PhD students over the REF period (Table 3) and are achieving our target cohort of 35–40 per annum. Numbers registered and starting in each academic year are given in Table 3.

Table 3	2008	2009	2010	2011	2012	2013
PhD Students registered (FTE)	125.5	112.5	111	115	132	>135
PhD Students starting each year	32.5	22.5	31	35	43	>42
Cohort completion/on-course (%)	97	96	100	100	100	100

- In 2009 we undertook a complete revision of our graduate training programme, which now provides a flexible and effective model for cohort-based training. We emphasise the importance of continued in-depth learning throughout the PhD programme.
- We operate a portfolio model of training in which PhD students create a tailor-made training package by selecting from a menu of ~40 courses, both internal and external, ranging from traditional lecture modules to small group and guided reading/tutorials. These and our Researcher Development Progamme (online modules developed with Epigeum won the 2010 Gold Global Impact Award) cover sections A to G of the Joint Skills Statement. We promote and encourage PhD travel and research exchanges, and encourage attendance at international training schools. Department funds are allocated to allow this. Progress is monitored by Graduate Studies Committee via formal reports and student-led blogs of project meetings.
- We are developing novel PhD training mechanisms to build strong interdisciplinary graduate-student cohorts, these are embedded in Durham's Doctoral Training Centre strategy. This includes projects (e.g. Cement/SMC^3) with industry where we exploit private-sector expertise to provide training in enterprise, entrepreneurship and project management boosting employability; we have also developed "team" supervision under this programme. We will launch the SOFI CDT in Soft Matter and Functional Interfaces in 2014.

Student and PDRA experience: An indication of the impact of our PhD training is given by the career destination and achievements of our alumni from the REF period:

- 63 of our PhD students spent between 1–3 month placements in the laboratories of their industrial sponsors both in the UK and abroad during their PhD tuition period.
- Academic collaborations allowed 22 PhD students to study for extended periods in international institutions, including Auckland, Bangalore, Mainz, Regensgurg and Virginia.
- Our PhD students are in high demand after completing their studies. Immediately after leaving Durham, 90 continued research in academia as PDRAs, 10 entered secondary school teaching positions, 63 entered the chemical industry while 23 began other careers.
- During the REF period, 20 of our PhDs/PDRAs took up academic positions world-wide within 3 years of completing their studies at Durham including posts in America, Australia, China,

Estonia, Hong Kong, Korea, Libya, Malaysia, Nigeria, Poland, Spain, Thailand and Turkey; Bath, Durham, Lancaster, Leeds, Newcastle and Northumbria.

- Several of our PhDs & PDRAs were awarded prestigious fellowships following their graduation: New (1851 Fellowship, UC Berkeley; RSC Dalton Young Researcher Award, 2011); Murray (Marie Curie, Lausanne); Lecointre (FNRS Fellowship, Louvain); Lloyd (Herschel Smith Fellow, Cambridge); Roberts (Ramsay, Bristol); Willans (Hodgkin Fellow, Leeds).

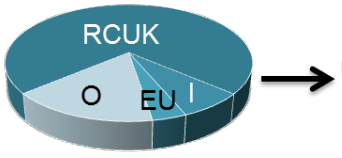
d. Income, infrastructure and facilities

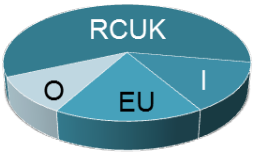
Research Income: In response to changes in the UK funding landscape, our goal since 2008 has been to increase EU (low in RAE2008) and industry funding and to target larger grants.

- *Diversifying Income*: we have placed increased focus on EU opportunities and have used Departmental/University seedcorn funding to test ideas and build relationships with strategic partners and wider industry. We have slightly increased income from research councils in period, but grown industry and EU support significantly to give an overall ~40% rise in research spend in period. This has led to a healthier balance of research income relative to 2008, with less reliance on research council funding:

RAE 2008 Funding

RCUK	72%
Industry	7%
EU	4%
Others	17%





RCUK	59%
Industry	14%
EU	17%
Others	10%

2011/12+ 2012/13 Funding

- *Major grants*: We've had success in winning major (>£1M) grants from various schemes: EPSRC Programmes (Hutson & Wrede; Sanderson & Bain); EU (Parker, Verlet); EU Networks (Bain, Bryce, Cameron, Cobb, Evans, Pohl, Sandford,); EPSRC Responsive Mode (Badyal, Dyer, Kataky); EPSRC equipment (Evans); EPSRC Fellowship (Low); Regional Growth Fund (P&G with 12 academics); EU/Japan (Prassides).

Infrastructure and facilities: The Department has continued to invest significantly in infrastructure (buildings and equipment) and technical support over the REF period to specifically support the research needs of our Research Groupings and individual groups. The process is managed by our Research Committee who oversee investment of Departmental and University funds.

- We have dedicated mechanical (3 staff), glassblowing (2 staff) and electronics (3 staff) workshops. A further 7 members of our technical team provide support in purchasing, safety, waste-disposal and building management. IT support is provided by 3 University staff embedded in the Department. Dr Mark Fox provides scientific computational support to synthetic research groups.
- Administrative/secretarial support for education and research is provided by a team of 9 people. We have 5 dedicated teaching laboratory staff.
- Through University and external (e.g. Wellcome) support, all laboratories have been renovated in the last 10–15 years. In the REF period: £2.8M have been invested to provide laboratories and infrastructure for BSI-related activities; £2.3M in heating/air handling infrastructure; a £1.4M project is renovating an industry-facing laboratory for process/flow chemistry; on-going investments (£600K) are improving the energy-efficiency of all our systems.
- Equipment has been supported by investment from the University, HEFCE, RCUK and industry. Through JIF/SRIF1–3 we received ~£6.6M in equipment funding. In the REF period we have invested a further £8M in equipment/infrastructure including solution state NMR (£700K), Mass Spectrometry (£1.1M), Crystallography (£1.5M), microscopies (£1M), materials characterisation (£600K), spectroscopy (£400K) and Hamilton high performance computing (£1.25M). This has allowed us to build up state-of-the-art equipment (Table 5). We have access to high-end shared electron microscopes in Physics (£1.7M investment in period) and Biology, and enjoy shared access to a range of other facilities across the Science Faculty.
- Equipment purchased under SRIF or with University funding is available without charge to all researchers; the overwhelming majority of equipment within research groups is also shared.
- Analytical services within the Department are "free at the point of access" to all staff. We believe this to be of particular importance in supporting junior staff. Major Research Services (NMR, Mass Spectrometry, Crystallography and Separation Science) are managed by staff at the Reader/SRO level and supported by 8 Experimental Officers/technicians. Minor research services are supported by 5.5 additional technical staff. Major/Minor services are given an

annual operating budget by the Department. Other services operate as "Facilities" and are funded collaboratively by individual research groups/groupings. Analytical services are encouraged to engage with external users to raise income and build links with industry.

	Table 4: Equipment (and Research Groupings it underpins)	
Major Services	Solution-State NMR (SMSI,OME,BC,SCC)	Agilent 700, 600, 400 and 200 MHz; Bruker 500, 400 MHz (x2)
	Mass Spectrometry (SMSI,OME,BC,SCC)	LTQFT; GC Trace; GCMS-QP2010; Autoflex II ToF/ToF; QToF Premier; LCT Premier XE; TQD; Xevo QToF; Synapt G2s HDMS
	X-ray Crystallography (All)	3 Bruker/Agilent small molecule single crystal instruments; ultra-low-T and high P diffractometers; Bruker RA protein diffractometer; X-ray reflectometry; small angle X-ray scattering
Minor Services	Separation Science (SMSI,BC,OME,SCC)	3 HPLCs (diode-array, fluorescence, UV-vis and RI detectors); Mass Directed AutoPurification System; GC-FID, GC-TCD; 2 ion chromatographs; Viscotek Trisec SEC (×2)
	Thermal Analysis (SMSI,OME,MSS,SCC)	2 PE TGAs with Hiden evolved gas MS; PE & TA DSCs
	Probe Microscopy (SMSI,BC,OME)	2 Leica SP5 confocal microscopes; Bruker and AIST-NT scanning probe microscopes for: semi-/non/contact, conductive, tuning fork and peak force AFM, LFM, advanced MFM, Kelvin probe, capacitance and EFM, STM, SNOM and 3D scanning imaging; nanolithography/manipulation capabilities and tip enhanced Raman spectroscopy (TERS); hot stage microscopy
Facilities/Other	Solid State NMR (SMSI,MSS,BC)	Bruker 500 MHz research instrument; 2×400 MHz in EPSRC national SSNMR Service; ultra-fast MAS capabilities
	Ion Beam Accelerator (SMSI,MSS)	NEC Pelletron accelerator: forward recoil scattering, Rutherford & non-Rutherford backscattering, nuclear reaction analysis, PIXE
	Materials Characterisation (MSS,OME)	5×Bruker high and low T powder X-ray diffractometers; QD SQUID magnetometer and PPMS (physical properties measurement system); XPS; environmental SEM; impedance rig
	Spectroscopy (SMSI,OME,BC,MSS)	Circular dichroism; CPL; spectro-electrochemistry; time-resolved luminescence IR and Raman microscopy; light scattering
	Miscellaneous/Other (All)	Quartz crystal microbalance; elemental fluorine facility; flow/process laboratory; high-pressure research laboratory
	High Performance Computing (TD)	HPC is provided via Hamilton, the University's 3500-processor core parallel supercomputer

- We work closely with partners in the N8 research intensive universities to develop and implement best-practice for infrastructure sharing. For example, High Performance Computing facilities located at Leeds augment local facilities and we submitted successful joint infrastructure bids under the 2012 EPSRC core capability call.
- We have run the UK's solid state NMR service, which is co-funded by EPSRC and industry, since 1985. This typically analyses 800 samples annually and has contributed to ~150 publications across the UK in the REF period. Funding for personnel and equipment upgrades has been secured for 2012–17 (£750K contract and £667K equipment).
- We have access to excellent library facilities with a 21% increase in Chemistry resource between 2008 and 2012 to £235K for books, journals and other publications. The University has invested an additional £1.5M on e-resources over a £3.3M pa budget, and funds are available to support open access. Library investment has led to a 42% increase in floor space and we enjoy excellent working relations with their staff.

Consultancy and Professional Services: Examples of activities include (more in Ref3a):

- *Consultancy*: 22 staff have individual consultancy contracts with 37 international and national industrial organisations including: Alere; Asahi Glass; BP; CDT; Clariant; DuPont Teijin Films; GSK; Michelin; P&G; Shell; Smartwater; Synthomer; Teva; Thomas Swan; and Unilever.
- *Public Policy and Professional Services*: 4 individual staff have contracts with 5 companies

worldwide to provide expert scientific advice for a variety of legal matters, including: Apotex; CISbio; Mayne Pharmaceutical; Novartis; Shibley and Liber; Simmons and Simmons; Spangenburg; and Sun Pharmaceutical.

e. Collaboration and contribution to the discipline or research base

As detailed in Section B, collaborative research lies at the core of many of our activities, and all our academic staff make significant contributions to chemistry locally, nationally and on the world stage. Tables 5 & 6 summarises some key data, and we highlight selected activities below.

Tab 5: Collaborations		Tab 6: Leadership & Service to Community	
Staff with collaborative publications Durham/national/international	26/33/36	National/international awards and named lectureships	23
Staff collaborating with biology/physics/other subjects	10/12/8	Staff elected to Royal Society FRS (current/emeritus)	3/3
Number of company interactions	>70	International advisory boards	14
Grants/Value with UK institutions	12/£20M	Keynote/plenary int'l lectures	256
Number of UK academic partners	20	Staff with int'l conference org'tion	24
Number of international partners	27	Editorial boards	38
Staff with visiting chairs or similar	11	Staff as EPSRC College members	20
Number of international visitors	>250	Staff on RSC/IOP/etc committees	24

Collaborations: Areas which exemplify our collaborative research and build specifically on our strategic aims (Section B) of partnerships, interdisciplinarity and internationalisation are:

- *Strategic Partnerships:* The Department and University have developed a strong strategic partnership with P&G, now involving 75 academics across the University. In Chemistry the Cement/SMC^3 project attracted £6M of RGF funding as part of a £15M project in surface modification and characterisation. The initial collaboration involved 12 academics, 8 PhD students and 3 PDRAs. Each subproject involves a collaborative team of ~4 academics and 2–3 industrial scientists. Our regular collaborative meetings have led to significant additional joint projects involving chemists, physicists, biologists, mathematicians and engineers. An additional 13 PIs, 7.5 PDRAs and 8 PhD students have since been involved in a range of funded projects. We are working successfully with CPI, one of the government's Catapult Centres, N8 partners and Research Councils to widen SMC^3 activities beyond RGF funding.
- *Other industrial collaborations*: We have collaborative research projects with >70 different blue-chip and other companies (http://www.dur.ac.uk/chemistry/industry) in period, informing and contributing to the Department research activity (partial or full funding for an additional 55 PhD and 10 PDRA researchers). Around 10% of our publications have industrial co-authorship. We support industrial collaborations by DTG funding, CASE and KTA schemes.
- *Other DU Departments*: We have extremely strong interdepartmental research collaborations with colleagues in Biology, Physics, Engineering, Mathematics and Earth Sciences. Much of this activity is inspired and enabled by our research Centres and Institutes (Figure 1). The co-location of 7 groups from Biological Sciences in Chemistry (each of which shares a desk room with a Chemistry group) helps foster collaborations. Our Natural Sciences undergraduate degree programme encourages collaborations to develop from the 4th year research project stage. Highlights of interdisciplinary research include Whiting, Cameron, Marder and Pryzborski on the synthesis of retinoids for controlling cellular processes and new polymeric scaffolds for 3D cell culture (1 PDRA, 6 PhDs) which was awarded the RSC's Rita and John Cornforth award in 2012; Hutson, Wrede, Cornish, Carty & Gardiner's joint EPSRC programme grant (A quantum gas of Ultracold molecules, £6.4M); Dyer and Greenwell (EPSRC MacroBioCrude, £1.6M); Kataky and Johnstone (EPSRC Biosensors, £1.2M); and the collaboration between Williams, Bryce and Monkman to develop new materials for optical applications (EPSRC £1.1M, 5 PDRAs). A number of staff hold joint appointments with other Departments (e.g. Carty, Hutson, McLeish and Staykova with Physics; Pohl with Biology).
- *International Collaborations*: 36 staff collaborate with colleagues in 24 countries world-wide which has resulted in 189 joint publications. Major funded international collaborations include: Prassides (EU-Japan Collaborative Project on light element molecular superconductivity, EU €1.6M, Japan, €1.8M); Hutson (US Air Force MURI project on Ultracold Polar Molecules, £3.8M); Bryce (Durham-led FunMols and Molesco Networks on molecular electronics, €6.8M);

Cameron (Durham-led EU Panoptes project on ocular drug delivery, €3.9M); Cobb/Sandford (Durham-led FLUOR21 EU Network of 7 academic and 4 industrial partners, €3.3M); Bain and Beaumont (MC-ITN with Bristol/P&G and 6 European partners, €3.6M); Evans (MC-EID industrial ITN with P&G, €1.5M).

- *UK Collaborations*: 33 staff collaborate with 75 colleagues in 23 UK Chemistry departments which has led to >120 publications. Notable examples include: Hutson & Wrede with ICL, EPSRC Programme Grant, Microkelvin Molecules in a Quantum Array, £6.4M; Bain & Sanderson with IC/Cambridge/Nottingham/Leeds, EPSRC programme grant: Sculpting Dynamic Amphiphilic Structures (PI Seddon), £4.8M; Bain and Badyal with Cambridge/Leeds, EPSRC programme grant (PI Hutchings), £5.0M; Bain and Hutchings with IC/STFC, EPSRC critical mass, £1.6M; Bain with GSK/Leeds, TSB (PI Sabey), £1.1M; Prassides with Liverpool on Superconductivity and magnetism, EPSRC, £1.1M. 12 staff collaborate with 30 colleagues based in UK non-Chemistry Departments, which has led to 33 publications.

Chemistry Community Contributions: Durham staff contribute to the national and international chemistry community in many ways. Examples include:

- *Publications*: Durham publications are highly cited. Our Departmental h-index within the 5 year REF period is already (October 2013) >55, with over 18000 citations in period.
- *Invited Keynote/Plenary Lectures*: All returned staff have presented their work at international conferences and the Department makes funds available to help staff attend when necessary. In-period 30 staff have given 256 invited keynote and plenary lectures at major conferences world-wide, as well as contributing to a large number of national and regional meetings.
- *Conference and School Organisation:* In-period 24 staff have served on national/international subject or conference organising committees. We also make use of Durham's facilities to host conferences and national training schools. Conferences hosted include: Cold/Ultracold Faraday Discussion (2009); RSC Dalton Discussion 12 (2011); RSC Directing Biosynthesis (2011); RSC Fluorine (2010); RSC Analytical research Forum (2012); British Biophysical Society (2012); IUPAC Int. Conf. on Physical Organic Chemistry (2012); Molecular Materials (2012); Advanced Polymers via Macromolecular Engineering (2013); Electroanalysis at the Nanoscale Faraday Discussion (2013); International Conference on DFT (2013). We have also organised/co-organised international PhD+ level training schools in Powder Diffraction and Rietveld refinement and single crystal diffraction methods every year during the REF period; these have trained ~500 students from around the world
- *Editorships/International Advisory Boards*: Staff serve on 38 international journal editorial boards including Editorships by Steed (Chem. Commun.), Hutson (Int. Rev. Phys. Chem.; Comp. Phys. Comm.), Prassides (J. Phys. Chem. Solids), Coleman (Graphene and 2D structures); and 9 staff serve on 14 international advisory boards including Bain (MPI for Colloid and Interface Research), Sandford (Prix Moissan board), Williams (AERES, France), Cameron (PoliMat, Slovenia), Parker (Chair of review panel, Leuwen; ANWUR, Italy; Royal Society URF and Wolfson Merit panels) and Howard (Royal Society Council and Elections).

Recognition: Awards for contributions to the discipline include:

- *RSC Award and Prizes*: Bain (Tilden, 2008), Tozer (Corday-Morgan, 2008), Parker (Mond, 2011), Hutson (Tilden, 2011), Prassides (Tilden, 2011), Coleman (Entrepreneur, 2011), Steed (Corday-Morgan, 2010; Bob Hay Award, 2008), Reinnervate team (Cornforth, 2012); Coleman (Times Higher Education Award for Research and Innovation, 2012).
- *UK Awards*: Parker (RS Wolfson Research Merit Award, 2004–2008).
- *Overseas Awards*: Parker (ERC Advanced Investigator Award, 2011–2016; Lecoq de Boisbaudran triennial rare earth science award, 2012); Badyal (International Association of Advanced Materials Medal, 2011); Hutchings (Arthur K. Doolittle Award – ACS PMSE Division, 2008); Hutson (Humboldt Research Award, 2010); O'Donoghue (Thieme Journal Award, 2013).
- *Election to Membership of Learned Societies*: Hutson (FRS, 2010).
- *Named lectureships*: Bain (Craig Lecture, Canberra, 2008; Thomas Graham, London, 2011); Hutson (Frontiers of Spectrosopy, Ohio, 2008); Bryce (Troisieme Cycle, Switzerland, 2008); Howard (Bragg Lecture, London, 2013); Parker (Distinguished Lecturer, Hong Kong 2013).