Institution: Newcastle University

Unit of Assessment: 8 – Chemistry

a. Overview

The UoA comprises 25 research-active academic staff. Research is focused into four interactive groupings: **Bio-medicinal Chemistry** (Cano, Carroll, Golding, Griffin, Hardcastle, Homans); **Catalysis and Synthesis** (Christensen, Doherty, Hall, Higham, Izod, Knight); **Chemical Nanoscience** (Fulton, Horrocks, Houlton, Pike, Tuite); **Spectroscopy and Structural Chemistry** (Baisch, Benniston, Carruthers, Clegg, Harriman, Henderson, Probert, Walker). Research strategy and delivery are overseen by a research committee comprising the Head of School and senior and junior academic staff representing all four groups. Since the RAE 2008 the UoA has restructured its research groupings to take into account strategic priorities (energy, medicine, materials, catalysis). A new Head of the School of Chemistry was appointed with 31 years industrial research management experience with BP, AKZO Nobel and SASOL, to take forward an operational strategy to build research excellence and impact for chemistry at Newcastle.

b. Research strategy

Our vision is to be world-class in the four areas of chemistry above and implement a research strategy to ensure that these are sustainable and of international standing. Our research groups reflect our existing and future strengths, important scientific challenges and opportunities: fundamental aspects of the chemistry/medicine interface and the development of drugs across an increasingly wide range of therapeutics, new electronic materials, environmental sustainability and understanding the properties of molecular-based materials.

The research strategy of the UoA has six main goals:

- Enhancing chemistry by the appointment of academic staff who are excellent researchers to strengthen the areas in the Chemistry-Medicine interface, Spectroscopy and Photochemistry, and Crystallography.
- Supporting and developing the activities of academic and research staff *via* effective PDRs and implementation of the research leave policy.
- Continually investing in and improving research facilities and infrastructure, including a 700MHz NMR spectrometer and a new Crystallography suite.
- Maintaining a vibrant research environment for staff and students alike, by refurbishing laboratories.
- Continuing to develop links with industry as exemplified by ASTEX, QuantuMDX and NewChem.
- Increasing the number and quality of highly motivated PhD students by providing school funded scholarships.

Over the past five years we have appointed six new full-time members of staff to the UoA (Baisch, Probert, Carruthers, Walker, Homans, Green). Three additional staff (Hardcastle, Cano, Griffin) have joined the School from the Faculty of Medical Science. Two new lecturers and two senior positions in Organic Chemistry will be appointed in 2013/14. A comprehensive review of infrastructure in the UoA was conducted in 2009 and research groups now occupy optimised, refurbished research facilities. This reorganisation has enabled the UoA to invest £250K pa in PhD studentships.

The UoA is committed to supporting research-active staff in pursuing their research goals through securing research grants and producing high quality publications. A full time research coordinator has recently been appointed to assist in the grant application procedure. As well as securing RCUK and EU funding, staff collaborate extensively with industry through contacts made via the Industry Advisory Board (IAB), personal contacts, North East of England Process Industry Cluster (NEPIC) and METRC. In order to ensure that the UoA is able to strategically advance its research activities and in addition to the appointment of new staff, a new generation of cyclotron and a 700MHz NMR Spectrometer have been acquired to increase our effectiveness and relevance at the Chemistry-Healthcare interface. Over £1.5million of Crystallography equipment has been installed along with new autoclaves to support catalysis research. Equipment sharing across the University has greatly enhanced our nanotechnology capability. The University hosting the National X-ray Photoelectron Spectroscopy Service is an example of this.

Relationship to RAE 2008
The plan for chemistry at Newcastle University (NU) as stated in the 2008 RA5 was that the 'Future research policy aims to build on existing strengths, promote new and emerging cross-disciplinary collaborations, and ensure the rapid development of recently-appointed staff.' Our existing strengths were identified as being in the areas of: molecular photonics, nanomaterials, catalysis and (anticancer) drug discovery. Research in these areas has continued to flourish since 2008, as highlighted by the substantive increase in research income and outputs and by the following research examples:

Spectroscopy and Structural Chemistry. Continued excellence in photonics research has been augmented by key discoveries in artificial light-harvesting arrays and in molecular photophysics. Advances have been achieved in our understanding and control of electronic energy transfer, culminating in the award of the 2011 RSC Chemical Dynamics Award to Harriman. Research has resulted in 70 publications in top-rated journals, generating seven cover pages in addition to two patents. A Royal Society Newton Fellow (Farras) is being hosted to work in this field.
Chemical Nanoscience. Our strength in chemical nanoscience has led to key advances in DNA-based materials. This relates, in particular, to the preparation and fundamental understanding of DNA-templated nanowires including details and modelling of their mechanism of growth and the development of new protocols for performing electrical measurements on such materials. The nanoscience group is involved in national and international research projects funded by Regional Development Agency One North East, EPSRC, TSB, government awards and EU (FP7, Marie Curie Fellowships, ITN), collaborations with industry e.g. INTEL, Akzo Nobel and the publication of 60 papers and filing of two patents. An in-house co-located SME (QuantuMDX) is successfully partnering us in grant applications (e.g. TSB) and substantive links have been created with the Faculty of Medical Sciences such as Horrocks together with the Institute of Cellular Medicine.
Bio-medicinal Chemistry. The quality of research from the Bio-Medicinal Chemistry group was recognized in 2010 by the award of the first CR UK prize for translational cancer research to Golding and Griffin together with colleagues in the Faculty of Medical Sciences for their discovery of PARP-1 inhibitors. The Newcastle group has repeatedly identified potent inhibitors of targets implicated in the molecular pathology of cancer, including inhibitors of DNA-damage repair (PARP-1 and DNA-PK), protein-protein interaction modulators (MDM2-p53), and inhibitors of kinases involved in signal transduction pathways. These internationally recognised activities have recently led to funding in excess of £7.5 M based on a landmark collaborative drug discovery alliance with Astex Pharmaceuticals (Cambridge). The new Cyclotron facility is leading us into newer therapeutic areas such as neurology (Carroll together with Institute of Neuroscience £1.076M).
Catalysis and Synthesis. Our strength in catalysis is demonstrated by advances in the development of catalytic chemistry of CO_2 as a means to develop carbon capture and utilisation. The research has been supported by 3 EPSRC grants (£179,371) and grants from TSB (£92,077), Carbon Connections (£95,737) and EU FP7 (£528,443) resulting in collaborations with University of Aachen, University of Twente, and eight companies, including Evonik and Sintef. Research has led to the publication of 16 papers, the filing of 3 patents and the formation of a spin-out company (Dymerix) to commercialise the research.

Other areas of research from the research groupings in the UoA continue to flourish, especially from new appointments and cover crystal polymorph chemistry (Baisch & Probert), functional polymers (Fulton), Diels-Alder domino reactions (Hall), synthesis of highly fluorescent biomarkers (Higham) and microwave spectroscopy (Walker). The long-standing collaboration of Doherty and Knight has seen the development of new methodology for the synthesis of architecturally distinct phosphines for applications in platinum group metal catalysis. Research from other established members of the UoA includes PET imaging (Carroll), polyoxometalate chemistry (Errington), mechanistic bio-inorganic chemistry (Henderson) and main group and lanthanide chemistry (Izod).

Future Research Strategy
We will maintain our research focus within the four stated groupings and to this end, new grants have been awarded for 2012-2013 totalling £4.733M. New proleptic appointments will be made into these groups over the next five years in line with the Faculty research strategy. One aspect of future research will be to address grand challenges set out as important areas, e.g. by EU, RCUK and the Government, for the UK to be internationally competitive. Future areas of research are

highlighted below:

Bio-medicinal Chemistry. Cancer therapeutics will continue as the area of medicinal chemistry within the UoA, with the important interactions with colleagues within the NICR (Northern Institute of Cancer Research) providing a key platform for the design, synthesis and testing of prospective anti-tumour agents. The expansion of cancer structural biology within the NICR, following the recent appointment of Endicott and Noble (UoA 1), will also be fully exploited for crystal structure-based drug design of anticancer agents. The bio-medicinal chemistry interface will be expanded into other therapeutic areas particularly where expertise already exists within the University, for example anti-infective chemotherapy and neuroscience.

Spectroscopy and Structural Chemistry*. Solar storage* -The application of light harvesting to material-based plastic voltaics forms the basis of new collaborations (Nottingham & St Andrews), and coupled solar fuels cells are the focus of a recently awarded Royal Society Newton Fellowship (Farras, £101,000). *Crystallography* – Work is expanding to encompass studies under extreme conditions, *viz*. ultra-low temperatures, high pressures and combinations of the two, using equipment developed by the newly appointed Probert in Durham and now transferred to NU; this is opening up new collaborations, such as a recently funded EPSRC project with Edinburgh and Glasgow. *Aerosol and Microwave Spectroscopy* - Two recent appointments (Carruthers & Walker) will focus on applying aerosol and microwave spectroscopy to new challenges in biology/medicine, remote gas sensing and catalysis. The appointments of visiting professors Anthony Legon (FRS) and Judith Howard (FRS, CBE) plus a new physical chemistry lecturer will consolidate and expand the research output of the grouping.

Catalysis and Synthesis. *Sustainable reactions* - There will be a continued research effort into atom efficient reactions focusing on multicomponent synthesis of bioactive molecules. Increasing the synergy between organic synthesis and biological chemistry will be a priority, with emphasis placed on the production of new antibiotics and the development of diagnostic tools for the biosciences (e.g. fluorescence microscopy, PET imaging). *Catalysis* - Increased emphasis will be placed on the synthesis of more environmentally friendly catalysts, in parallel with the identification of improved ligands for asymmetric catalysis and fluorescent chiral recognition agents. *Main group chemistry and mechanistic chemistry* - The design and preparation of multifaceted main group structures will continue, as will identification of new spectroscopic tools for fundamental biomimetic mechanistic studies.

Chemical Nanoscience. Future plans will involve a continued focus on developing methods for preparation/characterisation of functional nanomaterials for applications in electronics, as sensors, coatings, probes and drug delivery systems. In particular, research in directed-assembly of nanowire and nanoparticle components developed in the last REF period, including new solid-state and synthetic biology approaches, will expand with collaborations in academe (Bristol/Cambridge/EPFL *via* recent EPSRC and EU-ITN grants) and industry (e.g. Intel, AkzoNobel (An EU grant SEAFRONT will start in 2014 £1,284M), Alphasense and QuantuMDx - *via* a new TSB grant). New inter-group projects will also be initiated, for example in the field of nanomaterials for catalysis application, and we plan to expand in order to include collaborations or new staff in the area of computational nanoscience.

c. People, including:

i. Staffing strategy and staff development

Staffing strategy: The UoAs staffing strategy is to broaden and enhance its research base in a focused manner, in line with our research strategy and activities detailed above, by increasing staff numbers (where appropriate) and freeing-up current staff to perform research relevant to the overarching research strategy.

Academic staff: In support of this staffing strategy, since 2008 the UoA has converted two fixed term academic posts into open-ended posts (Hall and Higham) and has also made five new appointments (Baisch, Probert, Carruthers, Homans, Walker) in addition to promoting Cano, Fulton, Walker and Carroll to Senior lecturer, Hardcastle to Reader and Benniston to Professor, on the basis of their international research capability, research leadership, quality of research outputs, relevance to the UoA's strategy and significant grant income. A new Head of the School of Chemistry (Green) was also appointed. Additionally, UoA member Homans is currently Faculty Pro-Vice Chancellor/Provost, providing strategic leadership to the Faculty as a whole.

Higham and Hall were initially appointed to fixed term lectureships and these were made open-

ended in 2008/9 as a result of their excellent research potential in catalysis and synthesis. In 2009, Higham won an EPSRC Career Acceleration Fellowship (£703,501 with a £270,037 extension in 2012 under the New Directions for EPSRC Leaders scheme) and in 2011 Hall was awarded an EPSRC first grant (£98,914), which included funding for a temporary lecturer to allow him to concentrate on research.
In 2008, the UoA had four recently-appointed research staff: Fulton, Hall, Higham and Pike. Two of these, Fulton and Pike, were appointed on RCUK fellowships (2006-2011) and all were given minimal teaching and administrative duties to allow them to concentrate on their research. UoA funded PhD students were awarded to each fellow to allow them to initiate new research projects within strategically pre-defined areas. As a result, Fulton was awarded an EPSRC first grant (£330,517) in 2009 and has published 15 papers in high impact journals (Chemical Communications, Chemical Science). He has delivered invited lectures at the RSC Organic Division Meeting (2010), COST action CM1102 (Berne 2012), the RSC Chemical Nanoscience and Nanotechnology Symposium (NU, 2012) and the Warwick 2012 polymer meeting. Pike has developed research projects in the areas of molecular-functionalization of silicon, DNA-based materials and enzymatic routes to functional DNA through international collaborations with Wandlowski (Berne), Woolley (Brigham Young) and Ijiro (Hokkaido). He has been awarded a £1.3million research grant by the TSB (in collaboration with QuantuMDx, Magna Parva and Leaders in Oncology Care) and has presented talks in Japan, France, Germany and the UK. Additionally, in 2010, Baisch received a Marie-Curie reintegration grant (€45,000) following his previous Marie-Curie IEF fellowship. In 2012, Walker was awarded a 5 year ERC Starting Investigator Grant (€1,497,862). These awards and subsequent publications and activities illustrate the effectiveness of the UoA strategy for rapid development of newly appointed staff.

The appointment of Baisch, Walker and Carruthers arose from strategic decisions to support physical chemistry research and to strengthen and broaden Spectroscopy and Structural Chemistry. Thus, Baisch reinforces our already strong crystallography unit, whilst Walker and Carruthers develop spectroscopy into new areas (microwave and aerosol spectroscopy). Similarly, the recruitment of Homans was to strengthen and broaden the Bio-Medicinal Chemistry group, while the future recruitment to a new post within the Catalysis and Synthesis group will further advance research in the PET imaging area. The UoA has minimised Griffin's teaching load to enable him to focus on supporting the development of the Bio-medicinal Chemistry group. An additional new professorial post will further enhance our links with the Faculty of Medical Sciences. The UoA has appointed facility managers for NMR, and X-ray crystallography. A manager for the PET tracer facility will be appointed in the near future.

Within the UoA we aim to provide a supportive environment to encourage career development and progression. A six monthly Personal Development Review (PDR) process is used to facilitate academic career development. The PDR is used to respond to individuals' career development needs, for example, in research by encouraging and supporting them to submit grant applications and by making adjustments to staff workload. The UoA is working towards implementing a policy allocating a minimum of 50% of workload hours to research for Teaching and Research contracted academic staff (i.e. 900hrs of the notional 1800 workload hours), allocating additional research time to new academic staff within the first four years of their appointment (400, 300, 200, 100 hours), and implementing a formal policy for research leave for academic staff.

Research Associates (RAs): The UoA proactively supports RAs career progression. Individuals are encouraged to take part in the Career Pathways Framework for Research Staff which aims to assist RAs in planning their career development activities to support their future career aspirations in addition to using the PDR process. They are made aware of the extensive programme of training courses provided by NU Staff Development Unit. Within their research areas RAs are encouraged and supported to apply their skills through supervising and assessing undergraduate project students, giving tutorials, presenting at conferences and submitting research to high quality journals. All of these activities are supported by the UoA PDR process.

ii. Research students

Research students: NU operates an annual monitoring and review exercise for postgraduate programmes which covers all aspects of the student experience from recruitment, selection, training and progression to graduation. All research students enrol in the faculty researcher

development programme for generic research training. From the start of their PhD, students are encouraged to take responsibility for their research and this is implemented and monitored *via* a learning agreement and student-written research proposal. Each student's progression is monitored by an independent panel composed of academic staff and managed by the Director of Postgraduate Study. Every PhD student is allocated a supervisory team of at least two academic members of staff. The primary supervisor is responsible for the student's research, whilst the second supervisor is available to provide additional support to the student as required on a case by case basis. The increasing number of overseas PhD studentships is pro-actively managed by a committee that includes both home and international student representation and operates an on-going programme of recruitment visits by academic staff focusing on the USA, Far East and Europe.

Postgraduate students are represented in the UoA by the PGR forum and this body (run by the students) is active in arranging training activities including workshops on technical aspects of chemistry of broad interest. There are formal extensive opportunities for postgraduates to present their work as posters or oral presentations. The quality of the training provided to PhD students in the UoA is demonstrated by our excellent results in the 2011 PRES survey, especially regarding 'overall experience of the programme'. Awards won include: the silver chemistry medal at SET2012 (Higham student), People's Choice award at the Perspectives event of the 2008 BA Festival of Science (Houlton/Pike student), 2012 RSC Radiochemistry Group Young Researcher Award (Carroll student), best poster prize at the International Symposium of Electroanalytical Chemistry Shikata Discussion 2011 (Horrocks student), poster prize at the 2012 RSC young members symposium (Harriman student), Elsevier poster prize at the 13th Tetrahedron symposium (Cano student) and oral presentation prize at the 5th Biological and Medicinal Chemistry symposium (Hardcastle student).

The UoA operates a vibrant Erasmus exchange scheme providing an additional source of high quality PhD students. The scheme has involved 23 Erasmus students from partner institutions since 2008 (e.g. Giessen-Germany, Karagpur-India). The Erasmus scheme also provides academics, PhDs and PDRAs with the opportunity to visit partner institutions for scientific exchange and seminars. Six new Erasmus partner links have been established since 2008 and outside of Erasmus, similar links have been established with Australia (Monash, Sydney), Hong Kong and the USA.

The FTE number of registered postgraduate research students in chemistry at NU on 31st July of each year is shown in Table 1.

Year	Registrations
2012-13	66.68
2011-12	66.98
2010-11	76.59
2009-10	71.3
2008-09	64.38

Table 1

The completion rates for PhD students were (%) 2009 (69); 2010 (91); 2011 (100); 2012 (90); 2013 (Data incomplete). Recognising the need to further increase PhD numbers, the future strategy is to enhance overseas marketing by NU's INTO programme, keep improving research facilities to attract fully-funded students and maintain selective recruitment of academic staff in key thematic areas.

Annual events that contribute to the School intellectual environment include the postgraduate research day and the Wynne-Jones lecture at which students present posters judged by the Wynne-Jones lecturer (Gray, Breslow, Hindsgaul, Grubbs, Zare, Nicolaou and Bertozzi since 2008). There is a weekly seminar series within the UoA, which all PhD students are expected to attend and which features speakers from the UK and Europe as well as RSC prize winners from further afield. NU operates a visiting fellowship scheme to allow overseas academics to come to Newcastle as part of collaborative research projects. Selected exemplars include: Chatgilialoglu (Bologna) with Golding (*Org. Biomol. Chem.* 2012, 1102); Petrou (Athens) with Henderson (*Inorg.Chem.* 2011, **50**, 847); Al-Karawi (Baghdad) with Henderson (*Dalton Trans.* 2009, 564); Lincoln and Norden (Chalmers University, Gothenburg, 2011) with Tuite (*Chem. Eur. J.* 2012, **18**, 15142).

Equality and Diversity

The UoA is committed to achieving Bronze Athena SWAN status by April 2014. The University has achieved a Bronze award. In addition, Green is working with the RSC and local schools to promote interest in Chemistry within the black and Asian communities. Newcastle University is working with Durham University on a programme of activities to support women in Academia. The senior

women's coaching and mentoring programme is not only to develop the skills of the individuals involved, but to extend the network and provide a sustainable form of support to facilitate a positive change in culture. Newcastle University is also co-hosting a conference: Women and Change in HE: culture and careers 01-02/04/2014.

d. Income, infrastructure and facilities

Significant investment (£5M) has been made in terms of the infrastructure within the UoA since 2008, modernising in the process all fume-cupboard space and work areas. A major development has been the construction of the first dedicated PET radiochemistry laboratory and pre-clinical PET-CT scanners in the region, funded by multi-site collaborative platform grants (EPSRC Life Sciences £0.42M; EPSRC-CRUK-MRC-NHS £2.17M; MRC Neuroscience £0.6M with Imperial, KCL, GSK (now Imanova) and Manchester) with EPSRC chemistry project grants (total £1M+) providing key research personnel. Additional investment of £2M+ (including £625K from the Sir Bobby Robson Foundation) funded the installation of a mini-cyclotron and associated clinical production facility and an expanded QC laboratory. The cyclotron is the first of its type outside of the USA and NU is the demonstration site for this instrument. A new Medicinal Chemistry research laboratory has also recently been constructed by support of collaborative research with Pfizer (£400K).

Funding from Regional Development Agency One North East (£1.7M) and the Royal Society/Wolfson Foundation (£194,595) allowed the construction and equipping of a dedicated chemical nanoscience laboratory which provides ca. 500 square metres of self-contained laboratory and interaction spaces. The facility, which was opened in 2008, includes synthesis and chemical analysis laboratories with GPC, light scattering, electrochemistry and PCR facilities; spectroscopy laboratories, time-resolved fluorescence; Microscopy laboratories with scanning probe microscopy (AFM, STM, conducting-AFM, EFM, SECM), Raman, near-field and confocal fluorescence microscopies; Variable temperature electrical characterisation; Surface modification and characterisation (DNA synthesis, PEM-IRRAS FTIR, contact angle measurement, SPM); Laminar flow area; Materials printing facilities; Student and researcher offices and a conference room. This equipment supports collaborative research in nanotechnology with SMEs (e.g. QuantuMDX) and multinationals (e.g. Intel). The chemical nanoscience group has the capability to synthesise new materials, incorporate them into devices and to explore their electrical and optical properties.

The UoA operates three modern single-crystal X-ray diffractometers in a newly refurbished laboratory suite and provides an expert crystallographic service (Clegg, Probert and Baisch) to research groups as well as conducting cutting-edge structural chemistry research in its own right. Two of the machines recently installed by Probert are unique in the world, being custom built to provide access to sample environments close to absolute zero temperature and up to 10 GPa (10^5 atmos) with high-intensity X-ray sources. A powder diffractometer was recently installed, enabling crystallographic investigation of a wider range of samples, and the determination of structures from microcrystalline powders, an area in which Baisch is an expert. Until 2010 the NU crystallography group provided the very successful synchrotron component of the EPSRC National Crystallography Service. Since then it has led a regional project (with Durham) exploiting the single-crystal diffraction facilities of Diamond Light Source for examining the most demanding samples arising from research at both Universities and are among the leading users and most prolific publishers of results from this beamline.

The UoA provides an NMR service housed in a purpose-built NMR laboratory. This is based around four spectrometers (300-500 MHz) with autosamplers and VT units and is linked to a dedicated NMR network. The NMR facility is 'free at point of use' to members of the UoA. During this REF period we have installed a new 400 MHz NMR spectrometer and recruited a chemist (Wills) in 2010 to manage and develop all aspects of the facility. A new high-field spectrometer (700 MHz) fitted with a cryoprobe will be installed in 2014. This new machine will free up time on other spectrometers which will also be upgraded with new hardware to extend the range of experiments. It will also expand the interactions with the Faculty of Medical Sciences and Industry. In addition to carrying out research, the UoA provides a mass spectrometry service for academics, based around two high-resolution spectrometers (UPLC-ESI) and a high resolution MALDI-TOF spectrometer. The mass spectrometry facility is operated and maintained by two technicians who also provide an ICPOES facility. A new high-resolution sector spectrometer and an ICPMS facility

is planned to enhance capability further.

The Molecular Photonics Laboratory operates a range of computational chemistry facilities that are available to other research groups. Electronic structure calculations and molecular dynamics simulations are run on modern workstations which feature high end NVIDIA TESLA C2076 GPU cards and make use of dedicated software written to benefit from their rapid processing speed. The computer suite is managed by an academic staff member (Hagon) and is supported by a range of integrated Unix-running CPU clusters used to make quantum chemistry calculations (Gaussian, Turbomole, TeraChem, Spartan, NWChem, GAMESS) and molecular dynamics simulations (Tinker, Yasara, Materials Studio). Specialised software is available to calculate cone angles, transition density dipole moment vectors, electrostatic interactions and polarisation properties for Stark effect spectroscopy.

e. Collaboration or contribution to the discipline or research base

Collaboration: All staff of the UoA are encouraged to engage in collaborative research. The UoA and University support such collaborations by providing travel expenses and visiting fellowships as well as by making research facilities available to visitors. Below we highlight key examples.

A University Research Centre in Catalysis and Intensified Processing (URCCIP) was established in 2006 and has fostered new cross-disciplinary collaborations at the chemistry-chemical engineering interface. Work on reactor design for CO_2 utilization and the integration of chemicals and energy production has resulted in joint papers and industrial funding (Metcalfe, UoA12).

The radiochemistry facilities have already enabled collaborative research to be undertaken. An extensive, multi-disciplinary, research team has been established involving Griffin and Carroll in association with the NICR, Durham University (Parker) and Cambridge University (Griffiths) to embed medical imaging within their drug discovery and development programme allowing rapid *in vivo* evaluation of clinical leads and their translation through pre-clinical development to first-in-man studies. In addition to the oncology programme, the radiochemistry group also has joint projects with the Institute of Neuroscience and Clinical and Laboratory Sciences at Newcastle. A joint project with the University's Institute of Human Genetics and Cambridge on ^{18}F tagged DNA mimics for evaluation of as therapeutic agents for the treatment of Duchenne Muscular Dystrophy is also underway. A major collaborative programme is underway with Astex (Griffin, Golding, Cano, Carroll, Hardcastle (Chemistry) along with *Newell, Curtain, Endicott, Gaughan, Lunec, Maxwell, Noble, Reeves, Robson, Tweddle, Vormoor, Wedge (non-Chemistry*).

The isolation, structure determination and medical applications of novel bioactive natural products are being investigated by Hall in collaboration with Professor J. Errington FRS (Faculty of Medical Sciences) and Demuris Ltd., supported by a TSB grant. Hall has also established a collaboration with Burgess (UoA7) together with Institute of Cell & Molecular Biosciences and the Dental School in the area of biofilms. This collaboration has resulted in a UK patent (GB2477914), publication (PLoS ONE 2010, 5, 12, e15668), attracted three grants from NERC (£160K) and was a runner up at the UK Medical Futures Awards 2011. A licencing agreement has been signed with a large international company.

A KTA-funded project with High Force Research Ltd, is investigating the scale-up of known and novel medical imaging agents based on highly fluorescent molecules (Higham). Walker received a grant to collaborate with AWE Aldermasten on microwave spectroscopy. Golding has a long standing collaboration with Buckel (Marburg) on radical enzymes resulting in four joint publications and two Deutsche Forschungsgemeinschaft (DFG) grants totalling £350,000. Golding is the only foreign member of a multi-centre German consortium (funded by DFG from 2008-2014) studying the anaerobic functionalisation of alkanes, which has resulted in a leading joint publication (*Angew. Chem.* 2012, **51**, 1334).

Research within the *Spectroscopy and Structural Chemistry* group benefits from a number of long-standing academic collaborations with collaborators outside of NU which continue to be fruitful and include: studies on the photophysics of organic dyes (Harriman with Ziessel, Strasbourg; 21 publications since 2008 including 2 *Chem.Sci*, 3 *Angew.Chem*, 3 *J.Am.Chem.Soc*. and 7 *Chem.Eur.J.* with four cover pages) and main group metal chemistry (Clegg with Mulvey and Hevia, Strathclyde; 28 publications since 2008 including 1 *Nature Chem,* 1 *Chem. Sci*, 5 *Angew. Chem*, 2 *J.Am.Chem.Soc.* and 6 *Chem.Eur.J.*). Benniston has established a collaboration with

researchers in Moldova (Turta, Academy of Sciences) and Romania (Mangalagiu, Al.I.Cuza University) supported by a Marie-Curie FP7 grant (€190,800) to study photocatalytic clusters. New collaborations were established by Baisch with world leading groups in the fields of crystal engineering (Orpen, Bristol and Braga, Bologna; *Dalton Trans.* 2011, 4647, *CrystEngComm*, **2009**, *11*, 40); organometallic polymer chemistry (Poli, Toulouse; *Angew. Chem.* 2008, **47**, 6069) and medical research (Hügle, Basel; *Clin. Exp. Rheumatol.*, 2012, **30**, 240; Dinnebier, Max-Planck Institute for Solid State Sciences in Stuttgart; *J. Pharmacol. Sci.* 2013, **102**, 674.).

Contribution to the discipline or research base: Harriman was a panel member for the Netherlands Chemical Society Funding Initiative and for the US DOE Solar Energy Hub Review Board and follow-up review. He also visited and assessed Trinity College Dublin on behalf of Science Foundation Ireland. Errington organised an ESF Workshop on Polyoxometalate-based Nanoscale Devices and leads a COST initiative on 'Polyoxometalate Chemistry for Molecular Nanoscience' which includes 60 academic groups from Europe and Australia. Higham is a member of two working groups of the PhosSciNet network of European Research Groups on phosphorus chemistry. Houlton organises the annual Chemical Nanoscience Symposium.

In 2010, Harriman was appointed as the RSC's 'solar champion'. Clegg was a member of the working party for the design, construction and commissioning of beamline 19 at Diamond. He has also been the UK representative at the European Synchrotron Users' Organisation. Griffin was a member of the CRUK science funding committee and the Chemicals, Pharmaceuticals and Standards Expert Advisory Group of the Medicines and Healthcare Products Regulatory Agency (MHRA) and is a member of the external advisory boards for cancer research at Strathclyde and Queens, Belfast. Homans chaired the 2008-9 BBSRC national panel which reviewed high performance computing provision; is Deputy Chair of the BBSRC Bioinformatics and Biological Resources Fund and is a member of the BBSRC Tools and Resources Strategy and Exploiting New Ways of Working Strategy Advisory panels. He is also a member of the scientific advisory boards for the national NMR Centre (NIMR, Mill Hill) and the Henry Wellcome NMR centre (Birmingham). Higham was on the initial review panel for Centres for Doctoral Training (CDT) applications and Green was on the final panel.

Members of the UoA edit or sit on the editorial boards of over 20 journals including those published by the RSC (*PCCP*, Harriman) and ACS (*Acc. Chem. Res.*, Green; *Organometallics,* Izod; *J. Med. Chem.*, Griffin), they have also been guest editors for special issues of journals including *Chem.Comm.* (Artificial Photosynthesis, Benniston), *PCCP* (Electronic Energy Transfer, Harriman).

The number of invited/plenary lectures given by academic staff has increased since 2008. Exemplars include: Harriman, 13 plenary and 21 invited lectures including the NSF Symposium on Energy Storage from Sunlight (Kansas); Griffin, 18 invited lectures including the 13th Tetrahedron symposia (Amsterdam and Taipei); Homans, 2 plenary and 5 invited lectures including the 2009 Gordon conference on Biocalorimetry (Heidelberg). Clegg, 26 invited lectures including the American Crystallographic Association meetings in Toronto 2009 and Honolulu 2013. Benniston, 2 plenary and 9 invited lectures including the 239th and 240th ACS conferences. Houlton, 5 plenary lectures including QIES08 (Almuñecar) and 4 invited lectures. Golding, the 2nd Cedric Hassall lecture at ESBOC (Gregynog) and 7 invited lectures including the B12 Gordon Conference (Oxford). Fulton 4 invited lectures including two at RSC Meetings. Higham, 4 invited lectures including the 15th Brazilian Conference on Inorganic Chemistry (Rio de Janeiro). Cano, 8 invited lectures including at the American Association for Cancer Research Annual Meeting (Washington). Hardcastle, 8 invited lectures including the second European workshop in drug synthesis (Sienna).

Several members of the UoA have been conference organisers: Harriman was convenor for the 'Artificial Photosynthesis' symposium at the IUPAC Chemistry Congress (Glasgow), organiser of the 'Artificial Photosynthesis' symposium at ICPP-6 (New Mexico), co-organiser of a RSC Dalton meeting (Warwick) and a RSC Solar Fuels meeting (London), and chairman of Faraday discussions 155 on Artificial Photosynthesis. Benniston was on the organising committee for the 24th IUPAC Photochemistry Conference (Portugal, 2012). Griffin was joint organiser of an RSC Cancer Chemistry symposium (London, 2011) and on the programme committee for the 2008 NCRI annual cancer conference (Birmingham). He was also on the organising committee for the RSC-SCI symposia on kinase inhibitors in 2009 and 2011.