

Institution: University of East Anglia

Unit of Assessment: 8 – Chemistry

SECTION 1. UNIT CONTEXT, RESEARCH AND IMPACT STRATEGY

1.1 CONTEXT AND STRUCTURE OF THE UNIT.

This UoA8 return summarises research and related activities of 35 staff (34.2 FTE) working within the chemical sciences. The majority of these staff are based in the School of Chemistry which celebrated its 50th Anniversary in 2014 and today stands as a mature and dynamic research-intensive department. Also included are five materials scientists and three physicists from UEA's emerging Schools of Engineering (2021) and of Physics. All components of the Unit are physically co-joined, being within five minutes' walk of one another. They form part of UEA's Faculty of Science located on the Norwich Research Park (NRP). The Park comprises a partnership between UEA, the Norfolk and Norwich University Hospital and four independent research institutes – the John Innes Centre, the Quadram Institute, The Earlham Institute (all supported in part by the BBSRC), and the Sainsbury Laboratory (funded largely by the Gatsby Foundation). These partners form an extended campus containing one of the Europe's largest concentrations of researchers in the life sciences and the Unit plays an integral role in its activities.

The Unit's research is structured as three vibrant overarching themes chosen to be deliberately interdisciplinary and reflecting the breadth of our research activities: *Chemistry of Light and Energy*; *Chemistry of Materials and Catalysis*; and *Chemistry of Life Processes*. Our **dynamic research community** has a strategy to combine the pursuit of research excellence across the chemical sciences, with a focus on particular areas of strength, and productive collaboration across the Unit and beyond. Our staff enjoy excellent collaborative relationships with colleagues in sister Schools of UEA's Faculty of Science and Faculty of Medicine; and play integral roles in across-UEA and NRP-wide research centres.

Within each of its research themes the Unit connects chemistry at all scales, from molecules to materials and organisms, using state-of-the-art tools and approaches. Our work achieves significant impact and we value our excellent industrial links. Building on the successes of REF2014, the Unit has grown over this REF period through investment and income-generating success; for example, the number of academic research staff has increased from 25 to 35. In a competitive environment we have maintained an annual grant income of £2.7m and our outputs continue to be published in high-impact journals, including *Nature*, *Science*, *Cell*, *Advanced Science*, *Science Advances*, *Nature Commun* and *PNAS*, as well as the leading chemistry journals e.g., *Nature Chem*, *JACS*, *ACS Catalysis*, *Angew Chem* and *Chem Sci*. Over 70% of the outputs returned are in this group of journals.

1.2 RESEARCH STRATEGY AND PROGRESS AGAINST REF 2014 PLANS.

Our research has developed significantly over the assessment period, broadly in line with the plans laid out in the REF2014 submission and aided by a University-wide strategic **root-and-branch review** of our research and impact strategy led by the Pro-Vice Chancellor for Research & Innovation in 2015. To meet REF2014 plans there has been strategic investment through new appointments and infrastructure. Several significant interdisciplinary initiatives have emerged that cut across the core research themes e.g. energy materials, therapeutics/diagnostics, and synthetic biology.

Strategic research goals and successes, by theme

Chemistry of Light and Energy led by **Meech** aimed to:

- develop ultrafast laser spectroscopy and photonics;

- advance theoretical approaches to energy transfer and structured light;
- develop light-activated electron transfer systems.

Success in each of these areas is illustrated by the highlights of Box 1.

Box 1. Research Highlights: *Chemistry of Light and Energy*

- the discovery by **Meech** of the mechanism of off-to-on-state switching in the reversibly photoactivatable fluorescent protein dronpa, which is commonly used in super-resolution microscopy. *Nature Chem*, 2018
- theory from **Forbes** and **Andrews** describing the non-localised generation of correlated photon pairs during degenerate down conversion, with applications in quantum optics and imaging. *Phys Rev Lett*, 2017
- **Jones**' theory describing the importance of quantum coherence in condensed phase electronic resonance energy transfer, a fundamental process of energy capture in photosynthesis. *J Phys Chem Lett*, 2019
- measurement of heme-heme electron transfer dynamics in a bacterial nanowire protein by **Butt** and **Meech**. *JACS*, 2019

Chemistry of Materials and Catalysis led by **Bochmann**, **Cambridge** and **Hui** aimed to:

- increase capability in organic and inorganic synthesis;
- address major challenges in meeting future energy needs with focus on novel inorganic and/or bioinspired catalysts;
- develop and exploit materials for energy applications and therapeutics/diagnostics.

Illustrative successes of meeting these objectives are given in **Box 2**. The discovery and exploitation of materials with, e.g. novel fluorescence or thermoelectric properties, has developed significantly over the REF period.

Box 2. Research Highlights: *Chemistry of Materials and Catalysis*

Organic Synthesis and Catalysis

- **Bew**'s 'one size fits all' asymmetric synthesis protocol for incorporating stable isotopes into aziridines for new pharmaceuticals. *Chem*, 2016
- **Munoz**'s work on tandem cyclization/C-X coupling reactions through a novel Pt-Au heterobimetallic catalyst system. *Angew Chem*, 2018
- development by **Cambridge** of a simple synthetic route to hybrid systems intermediate between subphthalocyanine and porphyrin opening the way to further functionalisation of the parent systems, of growing importance in materials chemistry. *Angew Chem*, 2015

Next Generation Materials

- the discovery by **Romanov** and **Bochmann** of novel high-performance light-emitting diodes based on carbene-metal-amides, with applications in next generation electronic screen devices. *Science*, 2017
- **Chao**'s work in developing magnetic nanocomposite thermoelectric materials that overcome previously limiting performance deterioration problems. *Nat Nanotechnol*, 2017
- **Hui**'s strategies to deliver supercapacitors with enhanced mechanical and chemical stability for solid-state flexible energy storage. *Adv Sci*, 2018

Inorganic Synthesis and Catalysis

- **Wright** and **Bochmann** reported the first CO and CO₂ complexes of gold(III), with key relevance to the water-gas shift reaction for H₂ production. *Sci Adv*, 2015
- development of pioneering novel gold(III) chemistry resulting from **Rochigiani** and **Bochmann**'s synthesis of multiple examples of previously rare gold(III) hydrides, and the observation of their unprecedented reactivity in alkyne hydrometallation reactions. *Angew Chem*, 2016
- **Wright** and Pickett's studies of protonation rates of Fe-Fe bonds in complexes relevant to the function of hydrogenases and nitrogenases. *JACS*, 2014

Chemistry of Life Processes led by **Le Brun**, and embracing the Chemistry-led Centre for Molecular and Structural Biochemistry (CMSB), had the strategic goals to:

- further the application of novel biophysical approaches, including native mass spectrometry, pulsed EPR spectroscopy and protein film voltammetry, to understand biological mechanism;
- develop synthetic biology to engineer natural systems to perform new functions, with applications, for example in medicine and the energy economy as a new focus of research.

These were met as illustrated by the highlights in **Box 3**.

Box 3. Research Highlights - Chemistry of Life Processes

- the application of pulsed EPR by **MacMillan** to particulate methane monooxygenase, establishing that, contrary to previous reports, this enzyme contains two mononuclear copper centres with methane oxidation catalysed at one. *Science*, 2019
- pioneering work by **Le Brun** on the application of native mass spectrometry to provide unprecedented resolution of reactions at iron-sulfur clusters of regulatory proteins which underpin the ability of bacteria to thrive in e.g. the human body. *PNAS*, 2017
- **Butt**'s protein film electrochemistry revealing the distal His orients substrate for N-O bond cleavage in the wide-spread family of cytochrome *c* nitrite reductases. *JACS*, 2015
- **Sachdeva**'s development of photoactive antibody fragments, by genetic insertion of photocaged tyrosine, delivered to cancer cells in a light-dependent manner. *Angew Chem*, 2019

1.3 RESEARCH VISION FOR THE NEXT 5 YEARS.

Building on the Unit's tradition of inter/multi-disciplinary activities, our research structure provides a strong framework for progress in the next REF period in which we aim to advance fundamental understanding and address global challenges through activities that align well with both NRP and UKRI strategies. We are well placed to continue to attract funding from alternative sources including charities, industry and the EU (as developments permit) and to progress our research despite the challenges presented by COVID.

Research aims for *Chemistry of Light and Energy* build on the *Ultrafast Laser Laboratory*'s track-record of attracting significant investment from EPSRC for multidimensional nonlinear optical spectroscopy. **Meech** plans to develop ultrabroadband sources capable of probing coherence in simple chemical reactions with sub 5 fs time resolution in collaboration with the fast developing work of **Jones** in theoretical and computational excited state dynamics. Computational chemistry will continue to expand; in photonics and structured light through the recent arrival of **Forbes**, and through critical mass of theoretical expertise that includes coupled quantum and classical molecular dynamics (**Oganesyan**), and nanophotonics and radiation-matter interactions (**Andrews**).

Strong developments in multiple areas are planned for research in *Materials and Catalysis*. The *Energy Materials Laboratory*, led by **Wright** and **Fielden**, will continue to drive growth with, for example, **Fielden** building on his pioneering development of polyoxometalate non-linear optical chromophores through development of new, switchable bulk materials with potential applications in optical telecommunications and computing. The Unit's profile across organic and organometallic chemistry will strengthen in catalysis (**Munoz, Bew, Richards, Storr**) and synthesis (**Cambridge, Stephenson**). Developments in diagnostics and therapeutics will be driven by our new appointments, including **Lord's** studies of novel vanadium compounds for cancer treatment. Detailed 2D and 3D characterisation of material deposition, layering, and phase-separation are expected to advance printed electronics (**Alexander, Askounis, Mayes**), liquid crystal security films (**Cambridge**) and chemical sensors (**Melendi-Espina, Hernaez, Marin**). **Mayes'** development of novel methods for the detection of microplastics in marine (and other) environments is planned to advance significantly, at least in part, through UEA's strategic partnership with the Centre for Environment, Fisheries and Aquaculture Science (Cefas), a world leader in marine science and technology.

The CMSB will remain central to research in *Chemistry of Life Processes*. Research led by **Le Brun** will see further development of novel mass spectrometry to reveal new aspects of the enzymology underpinning bioelemental cycles. **MacMillan** will lead the application of pulsed EPR methods to transmembrane transporters important to health. **Sachdeva** will drive growth of synthetic biology towards application in therapeutics and, with **Butt**, for the production of 'green' electricity and chemicals. Collaboration with the NRP's newest institute, the Quadram Institute, is anticipated in analytical tool development for food and health studies (**Mayes** with Kemsley) and mineral/cofactor nutrition stimulated by their recent appointment of Warren and the new Norwich Institute for Healthy Ageing.

1.4 IMPACT: STRATEGIC GOALS, MECHANISMS AND ACHIEVEMENTS.

Regarding impact, our central strategic goal from REF2014 was to engender **a complete culture change to embed impact from research as integral to our mission**. This has been achieved through a variety of mechanisms and approaches, and with the support of UEA's central Research and Innovation Services, as evidenced by:

- Chemistry's Director of Innovation (**Oganesyan**) has active industrial links and regularly meets with ICS leads for progress updates, to offer guidance and signpost resources (financial and supporting) such that we have secured £393k impact funding from UEA's internal competitions;
- growth in the Unit's registered Impact Case Studies (ICS) from 5 to 16 over the assessment period. These are nurtured through discussion of impact activity in appraisal of all academic staff and by annual ICS review at both School and Pro-Vice Chancellor level in a dedicated University-wide process;
- protection of our intellectual property with 40 patent applications, 12 granted patents and 15 licensing agreements in the assessment period;
- the breadth and variety of our impact activities, which occur across multiple sectors including Agri-Tech (**Stephenson, Jayasooriya**), Energy Storage (**Chao**), Environmental (**Mayes**), Healthcare (Russell), and Display Technology (**Bochmann, Cambridge**);
- active encouragement and support of staff to establish and develop spin-out companies, e.g., Russell's Icen Diagnostics Ltd and Intelligent Fingerprinting as featured in two of our submitted ICS;
- active support of staff to pursue industry-related funding, for example **Romanov** and **Bochmann** secured major investment from Samsung;
- support, recognition and rewards for impact success through workload adjustments that reduce other duties and encouragement to enter UEA's annual Innovation and Impact Awards: Russell in 2018 was made one of only two UEA Innovation Fellows for outstanding achievements underpinning two of our ICS; **Mayes** won the ESRC Impact Accelerator Account Award (2019) for detection of microplastics in water; **Romanov** was shortlisted for

Unit-level environment template (REF5b)

Outstanding Commercialisation of Research Award (2020) for the development of novel materials for organic light emitting diodes technology.

These contacts and collaborations have **substantially enriched** the Unit's environment by providing support (direct or in-kind) for ongoing research, the basis for grant and impact funding applications, and direction to individual research projects of benefit to the researcher and the potential end-user.

1.5 IMPACT VISION FOR THE NEXT FIVE YEARS.

Alongside our three presented ICS, we have 13 case studies that exemplify the Unit's wider contributions to economy and society and which we are nurturing. These ICS illustrate engagement with a wide range of actors supported by the suite of mechanisms outlined above. Highlights for progress in the next REF period include:

- **Cambridge** working with OpSec Ltd and BASF to exploit his liquid crystal security materials (Patented in 2015) for use in next generation anti-forgery banknotes;
- **Chao** working with Changzhou Tonghui Solar Electricity Ltd (China) to exploit his research in silicon nanoparticles to enhance anodes for energy storage and with Biotronik SE & Co. KG (Germany) for implantable medical devices;
- **Mayes** developing technologies for detecting marine microplastic pollution. This has already influenced global policy. Mayes' technology was used to highlight the presence of microplastics in bottled water which led to a WHO global review of possible risks to human health;
- **Stephenson** developing water-resistant cellulose-based biocomposites for fibreglass replacement in the automobile sector, in conjunction with Heathcoat Fabrics, Coventive Composites and Element Materials Technology.

Our portfolio of case studies can be added to at any stage, is centrally managed and has access to substantial funding sources. Thus, we will retain our **agile response to new opportunities**.

1.6 APPROACH TO INTERDISCIPLINARY RESEARCH.

The Unit wholeheartedly encourages interdisciplinary research. This is facilitated by specific features and mechanisms within the Unit, for example:

- **joint, across-School staff appointments** (0.5 FTE in each School), with Hemmings and Butt each holding joint appointments between Chemistry and the School of Biological Sciences;
- facilitation of **across-School and across-NRP collaborations** via joint meetings and 'speed dating' events leading to interdisciplinary projects including Fielden's collaboration with Waller (Pharmacy) and Le Brun's collaborations with Balk and Buttner (John Innes Centre);
- membership of across-School and NRP-wide **research centres** each of which hosts a variety of workshops and seminars promoting interdisciplinary collaboration: the CMSB (linking to the School of Biological Sciences and School of Pharmacy); the *Earth and Life Systems Alliance* (a strategic research priority of the NRP linking to the School of Environmental Sciences, the John Innes Centre and other NRP institutes); the *Norwich Cancer Research Network* (linking to the Medical School, School of Pharmacy, and Norfolk and Norwich University Hospital).

1.7 RESEARCH INTEGRITY WITHIN AN OPEN RESEARCH ENVIRONMENT.

The Unit strives for **exemplary standards of research integrity** through a combination of University-level processes and the Unit's own activities. At University level, UEA maintains a Research Integrity Office and is a signatory of the revised 2019 Universities UK Concordat to Support Research Integrity and the Concordat on Openness in Animal Research. The University recently revised its Research Ethics Policy and all staff are bound by it and held to its requirements. At Unit level, we have sought to instil automatic compliance with the highest research integrity and ethical standards through strong emphasis of its paramount importance in all PGR student and Research Associate (RA) inductions.

We actively support an open research environment. This includes making our diverse research publications available to as wide an audience as possible, in line with UEA's Institutional Open Access Policy, through Open Access Journals and the UEA Digital Repository (>750 peer-reviewed journal/conference outputs appearing in >220 journals). In addition, data has been made available to all through the Open Science Framework and UEA's Digital Repository.

SECTION 2. PEOPLE

2.1 STAFFING STRATEGY AND STAFF DEVELOPMENT.

Our **staffing strategy** aims to create a **sustainable and thriving research environment** to facilitate the career development of existing research staff at every level, and to recruit outstanding new staff in open, fair competition. This includes attracting external fellowship holders and/or mentoring candidates as they apply for fellowships to be hosted by us. We aim to provide the highest standards of equality and diversity such that we attract, develop and retain high-achieving research staff and students.

2.1.1 Staff Development

To implement our staff development strategy we deploy a suite of mechanisms at University, Faculty and School levels:

- **Annual appraisal** for staff in all categories involved in research as follows:
 - For **academic staff**, including **research fellows**, annual appraisal is combined with the University's Research Activity Planning meeting in a single discussion led by the Head of School (**Le Brun**), Director of Research (here covering research and impact, **Butt**) and the Director of Learning and Teaching (Lancaster). The approach is *supportive*: achievements and readiness for career advancement are **celebrated**, and opportunities for support, training and career advancement are identified. Past record and future plans are discussed in detail, and goals agreed for the coming year in a process which encourages individuals to set realistic targets given the various demands on their time and energies;
 - For **contract research staff** and **research technicians**, annual appraisal is typically by the project's PI, but this can be changed on request. These appraisals also celebrate achievements and include career development and training needs. There is a focus on **optimising career development** for further employment when these staff are on short-term contracts. RAs are encouraged, where appropriate, to advance to fellowships or faculty positions (within the School and elsewhere), as exemplified most recently by **Hernaes, Marin and Rocchigiani**;
- The Faculty of Science has a **bridging fund** to cover short-term funding gaps of up to three months employment. This has provided continuity of employment for **Butt's** RA, van Wonderen, in a transition from EPSRC- to BBSRC-funded research;
- At University level, training and continuing professional development needs are provided by the Centre for Staff and Educational Development, which offers over 200 courses. It includes an **individual development funding scheme**, in place since 2014, for off-site specialised training requirements;
- The Unit fully supports UEA's Code of Practice for the Management of Research Staff, including management guidelines for Principal Investigators, that was recently revised to comply with the new **Concordat to Support the Career Development of Researchers**. UEA now offers **financial relocation assistance** to new contract research staff. It has also introduced a **merit-based promotions** process for contract research staff that accords with the revised Concordat, such that the University will fund any shortfall in funding for merit-based promotions and salary progression awards;
- **Flexible working arrangements**, updated comprehensively in 2019, are available to assist staff and include explicit criteria accommodating part-time roles and special circumstances (e.g. adoption/maternity/parental leave);

- **Chemistry's Promotions Committee** considers cases for confirmation of appointment and promotion of academic and contract research staff by implementing UEA's processes in the context of the standards of a thriving Chemistry department. The Committee, chaired by the Head of School, includes the Directors of Research, Innovation and PGR, as well as other senior staff in the School and an external member drawn from the Science Faculty. Supportive feedback on all applications, with general guidance for career advancement, is provided by the Head of School. We are keen to reward all staff for outstanding performance and collegiate activities within the School. Timely promotion applications are encouraged by e.g. a prompt to discuss promotion in the Appraiser Checklist that all staff receive. The effectiveness of our approaches is evidenced by the success of 12 (of 17) applications for promotion and all 10 applications for confirmation of appointment.

2.1.2 Staffing and Recruitment Policy.

We aim to recruit outstanding new research staff in open, fair competition. To this end, all staff undergo separate and mandatory training on: Recruitment and Selection; Diversity in the Workplace; and Understanding Unconscious Bias.

In accord with our strategy to 'grow' our own research talent by appointing at lecturer level, we have appointed 12 staff in the REF period to develop: novel ultrafast laser spectroscopy (**Bull** from University of Melbourne, Australia); medical diagnostics/therapeutics (**Marin** from within Chemistry and **Lord** from University of Bradford); synthetic chemistry (**Storr** from University of Nottingham, **Rocchigiani** from within Chemistry); synthetic biology (**Sachdeva** from MRC Laboratory of Molecular Biology, Cambridge); carbon nanomaterials (**Melendi-Espina** from the University of Nottingham, **Hernaes** from within Chemistry) and surface-patterning (**Askounis** from Kyushu University, Japan). Additional appointments included in this UoA8 are physicists affiliated with the School of Chemistry with expertise in: Bose-Einstein condensates (**Borgh** from University of Southampton), observational astrophysics (**Ferdman** from McGill University, Canada) and theoretical astrophysics (**Lander** from the Polish Academy of Sciences, Warsaw). Research and teaching in physics are spread across several Schools in the Faculty of Science including strong contributions from researchers in our *Chemistry of Light and Energy* theme.

We encourage research fellows to join the Unit and support their applications through mentoring, internal peer review and feedback. During the REF period we are proud to have hosted 4 Marie Curie Individual Fellows, a Newton International Fellow and a Daphne Jackson Trust Fellow. Independent research fellowships have also been won from highly competitive and prestigious schemes by **Romanov** (Royal Society URF), **Forbes**, (Leverhulme Early Career Fellowship) and **Lord** (UKRI Future Leaders Fellowship).

New appointments are provided with a mentor who guides them through UEA processes and supports them during their probation process. In common with all staff, they receive annual appraisal and access to the full range of staff development processes described above. Following successful confirmation of appointment, staff are free to retain their mentor, and senior staff are always available for additional advice and support.

There were three retirements during the assessment period (Page, Pickett, Russell) and replacement appointments were made in each of the corresponding themes. In addition, O'Connor moved initially to the John Innes Centre, NRP and then on to the Directorship of the Max Planck Institute for Chemical Ecology, Germany, while Wildgoose moved to a position in industry and Heisler to the Federal University of Paraná, Brazil. For succession planning, five of the staff submitted will be at traditional retirement age by 2027/28. Although the exact number choosing to retire is not known, our plan, founded on the continued success of the Unit, will be to replace each of these posts as they arise. For example, recent appointment of **Rocchigiani** is in preparation for **Bochmann's** retirement.

2.1.3 Support for Individuals at the Beginning of their Research Careers.

Those at the beginning of their research careers are integral to the strategy, culture and success of the Unit. Accordingly, we provide them with support through multiple mechanisms:

- **New faculty appointments** receive a formal **induction** led by the Head of School. They are mentored by a senior colleague, receive continued support through start-up funding provided by the School in accord with research need (£30k for lab-based, £15k for other), have priority in a Faculty-led PhD student competition that provides non-DTP-funded studentships; and have access to our DTP competitions. New staff benefit from participation in the MA in Higher Education Practice, and a lighter teaching load (building from approx. 30% to 100% over three years). These activities complement the support provided to all staff;
- **Newly-appointed contract research staff** receive formal induction led by the Principal Investigator of their project, which includes an induction to the School. A follow-up meeting at 3-6 months ensures 'all is well'. Mentorship by the PI continues throughout the individual's employment, reinforced by the annual appraisal. All contract research staff are offered the opportunity to be mentored in career development by a person other than their line manager. Mentorship and training include advice on preparing manuscripts for publication, grant writing and project management. Several of our contract research staff have been mentored in successful applications for grants as Researcher Co-Investigators (e.g. Bradley, Crack, van Wonderen). Others have been mentored to faculty positions (**Marin, Rocchigiani, Hernaez**) and prestigious independent fellowships (**Forbes**, Leverhulme ECF; **Romanov**, Royal Society URF);
- Chemistry uses indicative research job descriptions to ensure that RA jobs are costed at the correct level on grant applications and that appointments are made on an appropriate salary grade to reflect the level of knowledge and expertise required in the role;
- Chemistry's **Contract Research Staff Coordinator (Oganesyan)** acts as a point of contact and mentor for research staff and additionally represents their interests at meetings of the School's Executive Committee;
- The Unit encourages contract research staff to become, where appropriate, members of the supervisory teams of PhD students;
- The Unit supports contract research staff in presenting their work at dedicated slots in **Chemistry's Annual Research Day** and the **University-wide Annual Researcher Summit**, and the many opportunities to give research talks within the Unit, across the NRP and at national and international events.

2.2 RESEARCH STUDENTS.

Post-graduate research (PGR) students, PhD and Masters by Research, make an **essential contribution** to research in the Unit, and a significant contribution to its **intellectual viability and vibrancy**. Their supervisory programmes represent the means by which we train the next generation of confident, skilled research practitioners. Students have been funded from sources, including EPSRC, the Norwich Research Park BBSRC-funded DTP (in which Chemistry is a partner applicant), EU ITNs, Leverhulme Trust, The Big C, and institutional support via the Science Faculty. Our international PGRs are generally supported by overseas scholarships. All staff involved in PGR supervision and recruitment are trained in equality issues through mandatory training, reinforced by a requirement for PGR supervisors to undertake training in Best Practice in Research Supervision every 3 years as stipulated by UEA's Code of Practice for Research Degrees.

2.2.1 Approach to Recruitment.

The recruitment of PGR students adheres to UEA's policies on recruitment and Equality and Diversity including its Codes of Practice with respect to Protected Characteristics. We aim to recruit excellent students from as wide and diverse a pool of candidates as possible. Recruitment is via open calls followed by a formal selection process involving, as well as the proposed supervisory team, independent interview panels, Head of School, Director of PGR and the PGR Service. Recruitment panels are diverse and drawn from the full breadth of academic colleagues. Hence recruitment of PGR students is merit-based with full awareness of the requirement to

guarantee equality of opportunity to all. Evidencing the outcomes of this approach, within the Unit there is a good gender balance among PGR students (48% F for 2018/19).

2.2.2 Monitoring and Support for Research Students.

PGR students within the Unit are generally registered in the School of Chemistry. Their programmes are overseen by the Faculty of Science Graduate School and the **UEA Doctoral College**. In addition to frequent informal meetings, formal progress meetings mandated by the Doctoral College occur every 4 months and include an Initial Meeting, at the outset, and a Probationary Meeting within 12 months of starting. The Probationary Meeting has an independent chair and permits formal progression to the PhD programme.

Students have access to a number of sources of support and routes to have their voice heard: through their supervisory teams; Chemistry's **PGR Director (Sachdeva)** and **Deputy Director (Munoz)** appointed to retain gender balance; Chemistry's Disability Officer; the Science Faculty's embedded Well-being Team; Student Support Services at University level, and the **UEA-wide Courage Project**, an initiative of the UEA Students' Union to support PGR students with a particular focus on well-being and mental health.

PGR students have representation on the **Faculty of Science PGR Committee**, providing direct access to the Associate Dean of PGR and enabling students to shape PGR policy and culture. They are also supported through cohort-level events and activities. We place great emphasis on developing each year's intake as a cohesive group, providing students with a ready-made peer support group. All PGR students have a dedicated personal workspace, computer and lab space as required. More generally, we **celebrate PGR achievements** as an integral part of Chemistry's activities including: our Annual Research Day, a lively forum featuring talks and posters from PGRs; lunch with external speakers providing **diverse role models**; contributions to events such as the annual Norwich Science Festival, Royal Norfolk Show, Norwich Pint of Science and the Norwich-based Teacher-Scientist Network. Furthermore our PGRs can expect to present their work at ≥ 1 international conference, funded through their research training account which may be supplemented by the School. The **Science Faculty's Return to Work and Family Support Fund** offers additional funds to students with carer responsibilities.

There is **high satisfaction** among our PGR students demonstrated through the biennial **Postgraduate Research Experience Survey** where we significantly exceeded national averages in all questions. Averaging over the 2017 and 2019 surveys, Chemistry's PGRs reported 97% overall satisfaction and 95% satisfaction with the quality of supervision. Significantly, 98% felt confident in their skills development over their project.

2.2.3 Skills and Career Development for Research Students.

The **UEA Code of Practice for Research Degrees** ensures a commitment to the provision of transferable skills and employability training for all PGR students. Thus, as well as receiving bespoke research training from their supervisory teams, each PGR student follows a **bespoke Training Pathway** from the Faculty of Science or their DTP. These pathways outline mandatory requirements as well as setting out proposals for broader development, which are tailored to individual student needs. Students complete a Training Needs Analysis, on arrival and this is revised on an annual basis in a reflective process supported by their supervisory team and two dedicated Faculty of Science Training Coordinators.

Training is provided by a variety of qualified staff including: academics from across the NRP; two dedicated Faculty of Science Training Coordinators; staff from UEA's CareersCentral and the Centre for Staff and Educational Development. It takes a multiplicity of forms, ranging from advanced quantitative and/or technical skills training (e.g., NMR, High Performance Computing), through training in teaching, to broader professional skills (e.g., effective oral and written communication, project management, report writing, critical thinking and leadership). The training is evidence-based, responsive to students' needs (e.g., via feedback surveys for each event) and inclusive, with, for example, some events being delivered as webinars. Specific support for impact and employability is provided through mandatory **external placements** for students on projects

co-designed with external partners under the iCASE model and through Professional Internships for PhD students (PIPS) unrelated to their research for BBSRC-DTP students.

We are proud of both the research achievements of our PGR students and the broader skillsets that they acquire as a result of their training. Our PGR students co-authored 34% of our returned outputs and performed research that underpins our portfolio of ICS.

2.3. EQUALITY AND DIVERSITY (E&D).

The Unit is fully supportive of UEA's overall strategy and policies on E&D. In line with these frameworks, all staff undergo **appropriately tailored training**, refreshed every two years and that includes Diversity in the Workplace training.

E&D considerations formed an important part of the **workload model**, developed and implemented by the Faculty of Science in 2019 to replace the School based models. Using a consistent methodology, the new model allocates time for research which is transparent to all and accounts for part-time working. Taking a strategic approach the model allocates 30% of staff time to core research activities (proposal writing, responding to new opportunities, output writing and impact development), as well as protecting funding success by ensuring all awarded Investigator time is included as workload.

Through a mix of formal and informal approaches, the Unit strives to achieve a professional, supportive and inclusive research environment for all.

2.3.1 Specific E&D Measures within the Unit.

Beyond UEA's requirements, Chemistry is proud to hold **Athena SWAN Bronze Status**, awarded in 2016 and renewed in 2020 with recognition of 'the very clear internal checklists for planned leave, appraisals and induction'. We have **embedded Athena SWAN principles** within our processes. For example, aiming to increase the number of female academic staff, two of three appointments in 2019 were female, and we are committed to further increasing the diversity of our faculty. Moving forward, 'Bias Interrupters' will be used prior to all shortlisting and interview panels. As well as implementing the Action Plan, the School routinely collects data and conducts surveys of the views and experiences of staff and students with the aim of continually improving its E&D culture. These activities are overseen by Chemistry's E&D Committee. Composed of representatives at all levels, including the Director of Research (**Butt**), this committee meets every six weeks and the Chair (**Jones**) sits on, and reports directly to, Chemistry's Executive. **Jones** works with the Faculty's Athena SWAN E&D Project Coordinator to ensure the sharing of best practice and new ideas. **Jones** also sits on the Science Faculty's BAME committee for Physical Sciences.



The Unit seeks to achieve an **inclusive and supportive** culture. Flexible working and core hours accommodate personal need, maintain a healthy work-life balance and recognise the role of carers. **Flexible working**, in line with University policy, can be requested by all staff. School-level meetings (e.g. committees) and research talks are timetabled to fall within the designated **core working hours** of 10:00-16:00. Academic staff, researchers and PGRs also have autonomy to schedule their work around required attendance (e.g. teaching, training, meetings) and as allowed within safe-working practices.

Staff and PGRs with dependants, children or elderly relatives, can apply to the Science Faculty's **Return to Work and Family Support Fund** (a ring-fenced £10k p.a.) for e.g., help with care costs while attending conferences. This fund supported ad-hoc childcare for Chemistry faculty returning from parental leave, and an accompanying person to assist with child care during RA visits to the Central Laser Facility. The Science Faculty provided 12 months fixed-term cover to support the research, and deliver the teaching, of Chemistry academic staff during maternity leave and subsequent return to work. To enable return to work after a career break, the Unit supported the successful application from RA Ahire for a **Daphne Jackson Trust Fellowship** co-sponsored by the Science Faculty and Royal Society of Chemistry.

Our **supportive approach to well-being** is reflected in our aforementioned celebration of, and reward for, achievements in research, innovation and positive culture change. Appointment to senior roles is normally based on discussions at appraisal about the roles staff are interested in, with follow on discussion and consideration of workload. In some cases, open calls are used. This approach has broadened take-up of these roles, such that the **gender balance of the Chemistry Executive** (3F, 8M) is currently representative of the School's faculty.

All staff have access to **ResNet**, a UEA-supported network promoting equality and fairness across the NRP. **Blumenschein** and **Munoz** received Science Faculty financial support to attend Aurora, a women-only leadership development programme run by the Leadership Foundation for Higher Education. We observe well-being events (e.g. Time to Talk Day, World Mental Health Day), host seminars to enhance inclusivity (e.g. Decolonising Science), and solicit suggestions for well-being and inclusivity actions from staff and students. We celebrate International Women's Day, have held two seminars on decolonising the curriculum, and celebrate Black History Month with daily posts about BAME scientists.



2.3.2 Construction of the REF Submission.

This submission was constructed to present the quality of our research and impact while recognising, in compliance with **UEA's agreed REF2021 Code of Practice**, the need to maintain fairness and eliminate potential unconscious bias (all REF2021 decision-makers received Unconscious Bias training). Selection of Category A staff took two forms. Firstly, all staff employed on UEA contracts with significant responsibility for research were automatically included. Secondly, as per the Code of Practice, an open call across UEA solicited applications for Independent Researcher status. Applicants were assessed by the Pro-Vice Chancellor for Research & Innovation, aided by colleagues in the Research and Innovation Office, and added to the staff list as appropriate.

Selection of outputs from staff on the finalised staff list followed the procedures in UEA's Code of Practice. Outputs for potential submission were solicited from 2017 onwards by open calls, i.e. self-nomination. These outputs were considered at least twice in a series of assessments involving a combination of internal and/or external assessors. Internal assessment was carried out collectively, with each academic staff member contributing (6F:29M at the time of submission). External assessment was by senior researchers (1F:2M) to calibrate internal scores and gain additional opinion where internal scores diverged. All assessors received instruction to assess the output itself, were advised on how to minimise unconscious bias, and the process and outcomes were discussed by Chemistry's E&D Committee. Anonymised assessment scores were returned to staff, giving them the opportunity to reflect on and challenge them if desired.

Output selection in accordance with REF2021 rules was then based on quality both within and between each author's outputs by a panel of Chemistry's senior academics (2F:3M). The gender profile of attributed authors' outputs (14% F), reflects that of the Unit as a whole (17% F).

ICS selection was on the basis of a series of annual review meetings conducted by the School Directors and Faculty Associate Deans of Research and Innovation, the PVC Research and Innovation, and the Impact managers (typically 4F:3M). Constructive feedback was returned to authors at each stage.

SECTION 3. INCOME, INFRASTRUCTURE AND FACILITIES

3.1 INCOME HIGHLIGHTS

The Unit's research income was £18.6m over the REF period. We secured >£21.1m during the REF period with major funders including the EPSRC, BBSRC, NERC, Leverhulme Trust and ERC. For example: **Meech** won £1.25m (EPSRC) to develop ultrafast spectroscopy to probe dynamics in complex systems from materials to proteins, e.g. *Nature Chem*, 2018; **Oganesyan** won £700k (EPSRC) to develop computational methods for predicting EPR spectra from molecular dynamics relevant to lipid membranes, liquid crystals, DNA fragments and proteins e.g. *ChemPhysChem*, 2018. **Bochmann** won a prestigious ERC Advanced Grant 'GOCAT - Gold(III) Chemistry: Structures, Bonding, Reactivity and Catalysis' (£1.7m) facilitating e.g. *JACS*, 2018; **Butt** led studies of light-driven electron transfer in biohybrid assemblies, e.g. *JACS* 2016 & 2019, with collaborators in Leeds, Cambridge and UCL funded by BBSRC & EPSRC (£2.7m total, £1.2m to UEA). **Le Brun** won >£2m (BBSRC) to determine how bacteria, including pathogens, sense their environment through iron-sulfur cluster regulators, e.g. *JACS* 2019 & 2020.

The Unit's externally funded active awards supporting impact during the assessment period totalled £4.5m. Major external sources included from Samsung (£860k) to **Romanov** and **Bochmann**. Internal funding benefited **Bew's** spin-out company, IsochemiX, for high-value isotope synthesis; £28k from the PVC Strategic fund and £17k from UEA's Industrial Strategy fund to explore business growth opportunities in UK, EU and US. Russell's spin-out company Icen Diagnostics Ltd, a submitted ICS, benefitted from approx. £50k of internal impact funding to develop methods for detection and discrimination of human and avian influenza. In addition, faculty received >£170k from the Innovation Proof of Concept Fund, >£60k from the Innovation Development Fund, >£215k from the NRP Translation Fund, >£35k from the HE Impact Fund. Other notable successes include awards totalling >£450k from CERES an Agri-Tech partnership funded by Research England (**Stephenson**, Jayasooriya), BBSRC NIBB awards (including >£80k to **Le Brun**) and a BBSRC Sparking Impact award (**Le Brun**).

3.2 STRATEGY AND SUPPORT FOR GENERATING RESEARCH INCOME AND IMPACT.

Our strategy is to develop a **sustainable** income stream for research and impact activities by **mentoring and supporting staff** to develop their research agenda and to help identify funding opportunities with UKRI and beyond. For those that are less established we facilitate strong collaborations with leading peer research groups and make introductions to our industrial contacts, and we also actively encourage **interdisciplinary and collaborative proposals**. Future strategy is to grow our funding from EPSRC (e.g. through our new appointments), from UKRI consortia, and to continue to diversify our funding streams through e.g. commerce/industry and central government sources.

Staff are supported by **internal review of grant proposals** >£50k, a formal process performed by staff with a history of funding success. For example, applications to EPSRC are considered within the School, and to BBSRC are reviewed by a UEA-wide panel. To inform and encourage new applications, the Faculty regularly host **research and funding workshops**, for example, we had an EPSRC theme day in 2018 with a programme leader giving a keynote talk, presentations on 'tips to winning funding', a Q&A panel and a networking poster event. Such events provide an excellent way of developing a **positive research culture**: one that is looking ahead strategically for future opportunities for success. In 2019, a series of Innovation networking events brought together researchers from across the Faculty of Science to initiate collaborative research, and underpin UEA strategy, to address priority themes of healthy ageing, clean growth and future materials. Chemistry provides a modest budget (~£500 p.a.) to assist participation in conferences and industry networking events when alternative sources are not available.

Faculty are actively encouraged to apply for **study leave, fellowships and secondments** to allow extended focus on research and impact: e.g. **Lord** was awarded a UKRI Future Leaders Fellowship; **Mayer** secured study leave to concentrate on microplastics research; and **Butt** held

a Royal Society Leverhulme Trust Senior Research Fellowship. In accord with University policy, faculty can apply for a semester of study leave (at a frequency of approx. one in six semesters). Our new workload model includes strategic adjustments to allocate staff time for impact generation where appropriate.

3.3 INFRASTRUCTURE SUPPORTING RESEARCH AND IMPACT.

Our research infrastructure, comprising a range of **core and specialist facilities** reflects a modern, research-intensive Unit. Facilities are housed in individual research laboratories and in centrally managed Instrument Platforms of which six are of particular significance to the Unit: X-Ray, NMR, Mass Spectrometry, Elemental Analysis, Bio-Imaging and Structural Imaging. The Science Faculty also has extensive mechanical and electronics workshops.

Platform instruments are centrally bookable, available to researchers across the NRP, and used for consultancy work with external partners. Each Instrument Platform has dedicated technical staff, a platform manager and an academic lead providing a direct link to researchers and a de facto lead to inform investment strategies and lead strategic equipment proposals. Substantial investment has been made in the platforms during the REF period using a combination of externally-raised funding, UKRI capital equipment awards and matched funding from UEA. For example, the **Mass Spectrometry platform** underpinned **Le Brun**'s mechanistic studies of regulatory iron-sulfur cluster proteins e.g. *Nature Commun* 2017, *Chem Sci* 2017. The platform was enhanced by **Le Brun** leading two successful bids to the BBSRC ALERT fund providing an Inductively Coupled Plasma Mass Spectrometer (£349k in 2017) and funds for a high resolution hybrid MS/MS instrument (BBSRC/UEA, £690k in 2020). Funds for a new MALDI-TOF instrument (EPSRC, £328k in 2020) have been secured.

The **Bio-Imaging platform** benefitted from new confocal and widefield microscopes (UKRI/UEA, £500k in 2019); the **Structural Imaging platform** was boosted through a new **Scanning Electron Microscope** (£700k, UKRI Capital Award, 2019), and upgraded **Transmission Electron Microscope** (TEM) facilities (UEA, 2015) with a second TEM and scanning electron microscope available under the NRP sharing framework. The **X-ray platform** was revitalised by the purchase of new facilities for small molecule X-ray crystallography (EPSRC, £616k, 2018) and powder diffraction (UKRI, £170k, 2019). This instrumentation has already supported high profile publications e.g. from **Fielden** (*JACS* 2020) and **Bochmann** (*Chem Eur J* 2020, *Chem Mater* 2020). The **NMR platform** includes a solid state 400 MHz NMR (upgraded with fast MAS capability in 2016, EPSRC, £75 K) and 500 MHz spectrometer, the latter with its console upgraded in 2020. These sit alongside excellent facilities for biomolecular NMR, including an 800 MHz spectrometer upgraded to allow multinuclear solid-state measurements (UKRI, £107k in 2020). Funds have been secured to equip a second 500 MHz instrument with a new triple-resonance probe (UKRI, £84k in 2020).

The University's IT and Computing Service provides **centralised support for research computing needs** assisting >25 outputs in the REF period from **Jones** and **Oganesyan** on theory and computation. **High Performance Computing** has seen £520k investment year on year since 2014. It now consists of 425 computer nodes, 10 GPU nodes and 6 huge memory nodes, providing 8312 CPU cores powered by Intel Xeon processors.

Alongside the platforms, specific infrastructural facilities benefit clusters of researchers. For example, synthetic chemists benefit from **GC-MS** (EPSRC/UEA, £50k, 2019) and have secured funds for **semi- and preparative HPLC** (UKRI, £80k, 2020). **Analytical chemistry** facilities include stopped-flow FT-IR, stopped-flow UV-visible and time resolved spectro-electrochemistry, attenuated total reflectance FT-IR and new fluorescence spectrometers (**Fielden**, EPSRC/UEA, £61k, 2019) allowing life-time and anisotropy measurements that have supported several publications e.g., *JACS*, 2020 (**Fielden**), *Nature Commun*, 2020 (**Romanov/Bochmann**). Funding was awarded for a new Raman microscope (EPSRC, £250k in 2020) for microplastics research and materials science. The *Ultrafast Laser Laboratory* led by **Meech** houses a multi-dimensional multi-frequency ultrafast laser spectroscopy facility. The above facilities are maintained by recurrent inward investment from the Unit for running and maintenance costs, and technical support.

The Centre for Molecular and Structural Biochemistry (CMSB) laboratories are equipped with facilities for cell culture through to a unique array of **advanced spectroscopic techniques**. These include: room temperature circular dichroism (CD) and magnetic CD (**Cheesman *Nucleic Acids Res*, 2018**); pulsed multi-frequency, time domain EPR (upgraded with a new console £377k, 2020 and 6T superconducting magnet £302k, 2014) and multi-frequency continuous wave EPR and ENDOR spectroscopies (**MacMillan *Science*, 2019**). The **protein electrochemistry suite** has provided novel perspectives of enzyme activity e.g., *JACS*, 2015 (**Butt**). An LC-Q-TOF MS instrument with ESI source provides facilities for high resolution mass data (including folded proteins) underpinning studies of photosensitiser:cytochrome biohybrids e.g., *JACS*, 2019 (**Butt**). Researchers have ready access to facilities for rapid reaction kinetics, calorimetry and ultracentrifugation. Extensive advanced proteomics facilities are available through the NRP sharing framework. Funds for a new isothermal titration calorimeter (UKRI, £120k) were secured in 2020.

We are supported by **skilful technicians** (11.6 FTE) that provide a wide variety of services, from glass-blowing to NMR expertise. Recognising that some essential 'core' research equipment is difficult to fund through external grants, the Faculty of Science has a 'well-found laboratory' fund, typically spending £200-£300k p.a. on repairing, replacing or upgrading workhorse equipment. UEA's Institutional strategy for replacement of ageing equipment includes the PVC-Research Capital Fund, with a budget of £500k p.a. for co-funding with external bids e.g., for Chemistry's protein purification systems (BBSRC/UEA **Butt, LeBrun**) and the aforementioned MS facilities. Chemistry has also benefitted from Estates funding (>£2.8m) to upgrade Science Faculty infrastructure including fumehoods, refrigeration units, and the central nitrogen and argon supplies.

3.4 COLLABORATIVE USE OF RESEARCH INFRASTRUCTURE.

Unit members are **collegiate providers and users of shared facilities**. For example, our EPR facility underpinned **MacMillan's** collaboration with Northwestern University's Hoffmann and Rozenzweig on methane monooxygenase (*Science*, 2019). The ultra-fast laser facility has underpinned **Meech's** collaborations with Tonge (Stony Brook) and Miyawaki (RIKEN, Japan) to reveal the interplay of chromophore and protein dynamics in photoactive proteins (*Nature Chem*, 2018) and with Feringa (Groningen) to show excited state structural dynamics in molecular motors (*JACS*, 2014). Regarding usage of others' facilities, **Le Brun's** work on protein structures relies on time bought on the Diamond Light Source national synchrotron facility at Harwell (*PNAS*, 2019), as well as synchrotron facilities at Grenoble (*Nature Commun*, 2017; *JACS* 2019). In addition, we secured £1.6m of in-kind contributions for research on facilities including the Central Laser Facility (**Meech, Butt**), ISIS Neutron and Muon Source (**Chao, Wright**) (e.g. *Angew Chem*, 2016).

3.5 E&D CONSIDERATIONS IN ACCESSING RESEARCH AND IMPACT FUNDING AND INFRASTRUCTURE.

Access to research and impact funding, as well as the infrastructure and equipment of the Instrument Platforms and elsewhere, is open to all and is based on need and merit. All staff may therefore benefit from the mechanisms by which the Unit encourages research and impact, and have equal access to the Instrument Platform leads and, for impact, to the Business Relationship managers of the University's Research and Innovation services. Nonetheless, in line with the Unit's overall approach to E&D, we are mindful of avoiding unconscious bias in all decision-making for resource allocation. We provide targeted assistance to ECRs in grant preparation and facilities access. This includes through mentorship and access to Platform instrumentation to complete high impact research or pump-prime applications, in a process overseen by Science Faculty Research Executive.

SECTION 4. COLLABORATION AND CONTRIBUTION TO THE RESEARCH BASE, ECONOMY AND SOCIETY

4.1 RESEARCH COLLABORATIONS, NETWORKS AND PARTNERSHIPS

Collaborative, multi-disciplinary research is a central strategy for the Unit to meet its aims of addressing major scientific challenges through contributions that cannot be tackled by individuals or smaller teams. During the assessment period we published with researchers in 50 different countries (>55% of our outputs have an international collaborator), with numerous UK universities, and locally with researchers in other Schools at UEA and institutes within the NRP. Notable examples include:

- **Bochmann, Romanov** with Friend and Credginton (Cambridge) on high-performance light-emitting diodes based on carbene-metal-amides (e.g. *Nature Commun*, 2020; *Science*, 2017).
- **Le Brun's** work on iron-sulfur cluster global regulatory proteins involving collaborations with microbiologists including Todd (Biology, UEA, e.g. *eLife*, 2019), Green (Sheffield, e.g. 2017. *Nat Commun*), Hutchings and Buttner (both JIC, e.g. *J Biol Chem*, 2020), a structural biologist (Fontecilla-Camps, Grenoble, France, e.g. *JACS*, 2020), a resonance Raman spectroscopist (Johnson, Georgia, USA, *J Biol Chem*, 2015), a nuclear resonance vibrational spectroscopist (Cramer, UC Davis, USA), a Mössbauer spectroscopist (Kamali, Tennessee, USA) (*Angew Chem*, 2016)
- **Butt's** work on extracellular cytochrome electron transfer has led to a series of collaborative papers involving microbiologist Richardson and structural biologist Clarke (both Biology, UEA), biophysicist (Jeuken, Leeds), chemist (Reisner, Cambridge), computational physicist (Blumberger, UCL) and theoretician Cahen (Weizman Institute) with outputs including *Cell* 2020, *JACS*, 2019, *Chem Sci* 2018, and *ACS Catalysis*, 2017.
- **Stephenson's** work underpinned the 2018 launch of Open Lab Africa a consortium to build sustainable collaborative research capacity in sub-Saharan Africa and address the intractable problems of Neglected Tropical and Poverty related diseases. Academics from Tanzania, Uganda, Kenya, Ghana, Cameroon, Nigeria and the Democratic Republic of the Congo collaborate with UEA's Schools of Chemistry, International Development, Medicine, Pharmacy and Biology, and specialists in natural products networks (South Africa) and anticompetitive misuse of IP in the pharmaceutical sector (Australia). As a **UEA Vice-Chancellor's Global Challenges Research Fellow** Ngameni's (Cameroon) visit to Chemistry has resulted in 3 publications to date.

Collaborations are facilitated by all previously mentioned mechanisms for encouraging research and impact generation, support of interdisciplinarity, and underpinned by our overall **philosophy of mutual help and collegiality**. Logistically they are aided by the University's Research and Innovation Services and International Office.

4.2 RESEARCH IMPACT AND ENRICHMENT OF RESEARCH ENVIRONMENT

Our three submitted ICS were selected from a portfolio of 16 active ICS that exemplify the Unit's wider contributions to the economy and society. The contacts and collaborations engaged in these ICS, and nascent impact activities, substantially enrich the Unit's research environment by providing funding for staff research programmes, supporting bids for enhanced infrastructure, employing contract research staff to the benefit of both research teams and potential end-users, stimulating new lines of research, and enabling communication of our research with diverse communities.

Mayes' research in microplastics detection provides an impressive illustration of these **synergistic benefits** to our research environment, and evidence of the success of our culture of embedded support for impact. Mayes' new, rapid approach to microplastic detection (*Sci Rep* 2017), involved regional collaboration with Cefas. This methodology underpinned a study of microplastics in bottled water that led to a WHO review of risks to drinking water safety.

Subsequently, **Mayes'** study leave supported his contributions to a UEA/UKRI **Global Research Translation Award** in which he established the Malaysian Microplastics Network "MyMiP" (<http://mmp.umt.edu.my/>) to promote microplastics analysis and translate knowledge to policy and impact in a region heavily affected by plastic waste. NERC-funded infrastructure development for microplastics research at UEA (£250k), including laminar flow cabinets, enhanced the training received by network coordinator, Dr. Yet Yin Hee, during her visit to Chemistry as a **UEA Vice-Chancellor's Global Challenges Research Fellow**. Industrial engagement led to >£17K in microplastics-related consultancy and he was successful with competitive bids for >£43K of UEA proof-of-concept and impact funding. Mayes' ongoing research benefits from a senior research associated funded through the NERC Highlight Topics consortium grant *MINIMISE: current and future effects of microplastics on marine ecosystems* led by Galloway (Exeter), and funding secured for a Raman Microscope (EPSRC, £250k) to enhance microplastic analysis capability, among other projects.

4.3 ENGAGEMENT WITH DIVERSE COMMUNITIES

The Unit runs a full and varied programme of public engagement delivered by researchers at all career levels. By means of events, Facebook page and Twitter feed we aim to communicate our research and impact achievements to as wide an audience as possible. Moreover, in line with UEA policy, we demonstrate the high value we place on engagement activities by including them as one of the criteria considered in promotion. Individual engagement events and staff are too numerous to mention, but some highlights over the assessment period include:

- **Ashworth:** received the *Royal Society of Chemistry Inspirational Member Award 2018* for outstanding dedication to inspiring school students and the public. He sits on the advisory committee for Scifest Africa, an NGO, served on OPEN (formerly Schools Outreach Support Network Advisory Group) group for the Institute of Physics, and was recently appointed to the Norwich Science Festival Steering Committee. He has performed *Kitchen Chemistry* demonstrations in >12 countries to a total audience >10 000 with members from all age groups. With the RSC's *Spectroscopy in a Suitcase* he has reached approximately 700 sixth form students to showcase our research in physical chemistry while offering practical experience of IR and UV spectroscopy;
- **Butt's** exhibits in 2018 on biomolecular wires at the Latitude Festival and Norwich Science Festival attracted >2 000 participants;
- FutureLearn MOOC "*Biochemistry: The Molecules of Life*" in collaboration with the Biochemical Society (£20k, 2015) draws on **MacMillan's** expertise in membrane proteins. This 3-week course, for 15-19 year olds, held 15x has >30000 learners from >190 countries.
- **Marin's** presentation for MPs as part of SET for Britain at the House of Commons (2014) was awarded the *Roscoe Medal and Westminster Gold Medal* in Chemistry and featured research underpinning one of our submitted ICS;
- **Mayes** won a UEA Engagement award (2018) and ESRC Impact Accelerator Account Award (2019) for diverse work in science engagement and communication, e.g. Scientist in Residence in Groundwork Gallery, a story on BBC One's News at 10 (reported by >500 media channels world-wide within 24 hours), demonstrating plastic in tea bags in BBC's 'War on Plastic with Hugh and Anita – The Fight Goes On' (broadcast in 2020, >3.5 million views).
- **Mayes** organised the WWT Water Quality Conference Preconference workshop on Microplastics (2020) where an audience of >50 water quality and regulatory professionals explored the implications of microplastic pollution to the UK drinking water industry.

4.4 PROFESSIONAL CONTRIBUTIONS TO THE DISCIPLINE, ESTEEM AND RECOGNITION.

Service on **grant committees** includes: **Cambridge** as expert evaluator for EU Marie S Curie International Training Networks and Individual Fellowships programmes, **Le Brun** as a core member of BBSRC grants committees and the Royal Society's International Exchanges and Newton Advanced Fellowships panel; **Meech** as Chair of EPSRC Panels (Fellowships, Strategic Equipment). In addition the Unit has provided **expert reviews** to >25 overseas funders of research personnel and facilities, and >140 journals.

Contributions to **learned societies**, include: **Andrews** as Chair-elect of the International Society for Optical Engineering (SPIE); **Blumenschein** as Secretary of the British Biophysical Society; **Cambridge** as elected member of RSC Materials Division Council; **Le Brun** as Chair of the RSC's Inorganic Biochemistry Discussion Group and member of Dalton Council.

Faculty have given **numerous invited lectures** over the REF period covering the full range of the discipline. Our leading roles in **conference organisation** included as chair: **LeBrun** for Dalton 2016, a biannual joint Interest Group meeting of the RSC Dalton Council, ~350 attendees; **Butt** for the international conference '*Extracellular Electron Transfer: Mechanisms and Opportunities*' (UEA, 2017 sponsored by the Biochemical Society and EPSRC); **Munoz** for RSC Organic Division South East Regional Meeting 2016, ~100 delegates from academia and industries. We also contributed to organisation of: 18th International Conference on Time-resolved Vibrational Spectroscopy (2017) ~170 attendees (**Meech**); 2017 Joint Congress of the International Union for Pure and Applied Biophysics, Institute of Physics and British Biophysical Society (**Blumenschein**); RSC's Chemical Nanoscience and Nanotechnology Symposia in London (2018) and at UEA (2019) (**Chao**); 5th World Congress on Chemical Engineering and Catalysis held in Tokyo, Japan in 2018 (**Hui**).

Our contributions to **training of PGR students and RAs** included: an Industrial Summer School and Public-Private Cooperation Workshop for PGRs from 5 of Chemistry's organic chemistry groups through the EU Interreg-funded (€988k) 'Academy-Industry Chemistry Channel'; a Biochemical Society sponsored workshop 'Biophysical Techniques for Probing Metals in Biology' for UK PGRs (**Cheesman, MacMillan, Le Brun**); modules on advanced EPR methods at >6 COST-EU Training Schools (**MacMillan**); protein electrochemistry within the EU Horizon 2020 'BISON' project (**Butt**).

Faculty have held **editorial roles** with many journals. Senior examples include: **Andrews**, *Applied Sciences, European Journal of Physics and Symmetry*; **Le Brun**, *Microbiology, J. Biol. Inorg. Chem.*; **Mayes**, *Chemosensors*; **Meech**, *Journal of Photochemistry and Photobiology A Chemistry*. **Andrews** was also Editor-in-Chief of '*Comprehensive NanoScience and Nanotechnology*' 2nd Edition, Elsevier, 2019 and the '*Nanophotonics*', Elsevier book series.

Authorative reviews from the Unit include those by: **Rocchigiani & Bochmann** (*Chem Rev*, 2020); **Munoz** (*Chem Soc Rev*, 2014, >100 citations), **Hui** (*Adv Sci*, 2018, >60 citations and *Materials Horizons*, 2020), **Sachdeva** (*Nature Rev Chemistry*, 2020), **Le Brun** (*Acc Chem Res*, 2014, >70 citations), **Butt** (*Royal Society Interface*, 2015 >100 citations).

Faculty who have won **prizes evidencing leadership in their disciplines** include:

- **Cambridge**, *Hilsum Medal* 2016 from the British Liquid Crystal Society for contributions to the development and understanding of the chemistry of discotic liquid crystals;
- **Bochmann**, *RSC Applied Inorganic Chemistry Award*, 2017 for insightful contributions to industry-relevant catalysis research leading to significant economic and environmental impact in industrial olefin polymerisation processes;
- **Le Brun**, *RSC Joseph Chatt Award* 2018 for contributions to the understanding of molecular mechanisms of bacterial gene regulation by environmental levels of oxygen, nitric oxide and iron employing iron-sulphur clusters.