

<b>Institution: University of Glasgow</b>
<b>Unit of Assessment: 8</b>
<p><b>1. Unit context and structure, research and impact strategy</b></p> <p><b>School Structure and Context.</b> The School of Chemistry (hereafter the “School”) is one of seven schools within the College of Science and Engineering (CoSE) at the University of Glasgow (UofG).</p> <p><b>Research Group Structure and Research Themes.</b> In REF2014, the School made a joint submission with the Department of Chemistry at Strathclyde as WestCHEM. WestCHEM was created to strengthen chemistry research in the west of Scotland. Whilst WestCHEM still exists and our PGRs benefit from lectures and courses at either university, Glasgow Chemistry’s growth over this REF period in infrastructure and staff numbers has led to an expansion of research themes and a broader pool of major grant holders. The School has developed significantly and has further enhanced its unique and independent identity. Substantial new investment in Glasgow Chemistry has provided an expansion in staff, space and equipment, reflecting UofG’s confidence in the School. We have appointed and nurtured new staff, developed mid-career staff through promotion, and encouraged interdisciplinarity. Strategic investment has focussed on strengthening the research groupings, which can be demonstrated by the significant increase and spread of research council funding and by the increased quality of outputs (see below for full details). This has led to our decision to prepare an independent submission.</p> <p>To best exploit our wide-ranging research over this REF period, the School has been organised into six closely interlinked research clusters based around:</p> <ul style="list-style-type: none"> <li>• <b>Chemical Biology and Precision Synthesis (CB&amp;PS)</b>, developing chemistry to understand biology (9 staff),</li> <li>• <b>Chemical Photonics</b>, working on spectroscopy, (chiral) plasmonics, biophysics, and soft condensed matter (7 staff),</li> <li>• <b>Complex Chemistry</b>, constructing complex functional molecular architectures not based on biologically derived building blocks (7 staff),</li> <li>• <b>Energy Conversion and Storage (ECS)</b>, addressing the global challenges of climate change (7 staff),</li> <li>• <b>Heterogeneous Catalysis</b>, applying a fundamental understanding to catalytic processes to achieve sustainable development (4 staff),</li> <li>• <b>Supramolecular, Electronic and Magnetic Systems (SEMS)</b>, focussing on the nanoscale self-assembly of functional materials (7 staff).</li> </ul> <p>Each of these has a cluster leader (<b>Sutherland, Kadodwala, Cronin, Skabara, Lennon, and Murrie</b>, respectively). We have identified and developed new research themes during the REF period, including setting up new clusters (ECS and SEMS), with the potential for future economic, environmental and health impact in the UK. The clusters were assembled around our research strengths and we aim to be deliberately unique (e.g., Chemical Photonics and Complex Chemistry). These clusters provide a dynamic and flexible organisational structure to accommodate and manage changes in research interests and funding patterns whilst ensuring a coherent research direction and strategy. All R&amp;T academic staff reside in one cluster (affiliate membership of additional clusters is possible), although there are many cross-cluster collaborations (see below). We aim to go from fundamental research to real impact. As a single example, <b>Kadodwala</b>’s research on chiral plasmonics utilises close collaboration with other Schools and has developed over the REF period from fundamental research to increased industrial engagement. This has been enabled through mentoring of <b>Karimullah</b>, who was awarded a UKRI EPSRC Innovation Fellowship to work with companies including Horiba.</p> <p><b>Management Structure.</b> The School’s operations are overseen and organised by the School Management Group (SMG) comprising the Head of School, Head of School Administration, Head of Technical Services, Head of Teaching, Director of Research, Impact Champion and each cluster leader. We have recently added an ECR representative to ensure that the voices of early career researchers are heard. Several key individuals report to SMG including the School’s Athena</p>

## Unit-level environment template (REF5b)

SWAN Champion (**Thomson**). SMG has also representatives from other committees e.g., Safety, Teaching, and Research.

**Research Strategy and Objectives.** Our vision is to deliver internationally excellent and leading research that has the potential to produce the maximum economic, environmental and health impact for the UK; this has been an evolving process during the REF period and has directed our growth and recruitment strategy. Our research strategy is led by the School's Research Committee (chaired by **Skabara**, Director of Research). Since REF2014, we have sought to achieve these objectives within the context of our strong engagement and College leadership of the Athena SWAN process, fully embedding principles and working practices that support Equality and Diversity. As a consequence, the School's Athena SWAN Bronze award was renewed in November 2018.

Our strategic objectives over the current REF period changed from those prior to REF2014, reflecting our decision to focus on the School as opposed to a joint WestCHEM submission. Our objectives have been to:

- increase the size of the School, with particular emphasis on providing critical mass in the areas of CB&PS, Complex Chemistry and ECS where we see potential for real growth in future years. Hence, we have strategically invested now with a view to the future. We have recruited internationally excellent researchers strategically to strengthen key areas, develop new areas and facilitate succession planning. Over the REF period, we have appointed **Adams** (2016), **Docampo** (2020), **Draper** (2018), **Farnaby** (2016), **Gibson** (2017), **Hedley** (2018), **Jamieson** (2016), **Karimullah** (2018), **Köhnke** (2020), **Parrilla-Gutierrez** (2020), **Peveler** (2019), **Schmidt** (2019), **Skabara** (2018), **Thomson** (2016) and **Vila-Nadal** (2019).
- strategically foster a more engaged, interactive research culture, implementing new mentoring and internal peer-review processes and encouraging and rewarding collaborations across UofG.
- enhance and diversify our research activities, funding base and funding sources significantly. We recognised that in REF2014 our research income was reliant on too few individuals and too few funding streams. Our strategic appointment and mentoring strategy has resulted in currently 20 staff holding 48 active EPSRC awards on 31/7/20. We have active grants from EPSRC, BBSRC, Wellcome Trust, MRC, Royal Society, Leverhulme Trust, EU, as well as many industrial funders.
- grow our already strong engagement with industry to maximise impact. We have invested time in developing new processes here (see Facilitating Impact section below).
- strengthen and cement our international reputation as a leading centre for Chemistry world-wide. There has been significant investment from UofG in the Joseph Black (Chemistry) building, including £16.6M for refurbishment which simultaneously preserves the iconic architectural heritage whilst providing state-of-the-art facilities to undertake chemical research, including investment in new core instrumentation such as a new SQUID magnetometer, mass spectrometry, X-ray diffraction, thermal analysis, Raman and circular dichroism. We were awarded £693k in the recent EPSRC Core Equipment Award to invest in further infrastructure in 2021, linked to our grant income from EPSRC. We have targeted investment in equipment and start-up for new staff, including capital start-up, direct PDRA support and PhD studentships during the REF period.

**Progress and achievements since REF2014.** Since REF2014, the key strategic change has been to focus on the School as an independent unit rather than as a component of WestCHEM. Confidence from UofG has resulted in significant investment, an increase in the number of staff and a re-focus on our research direction. The strength and success of the School's research strategy is clearly demonstrated by £39.5M of research income in the current REF period. There is an increased number of high impact papers (staff have published >1200 papers in peer-reviewed journals; these include 51 Science and Nature group); these outputs along with the substantial investment in our building and infrastructure as well as 15 strategic new hires, places

the School on a clear, upward and sustainable trajectory. Specific research achievements in this period in each of our clusters include the following:

**Chemical Biology and Precision Synthesis:** Strategic investment in chemical biology includes the appointment of **Jamieson, Thomson and Köhnke**, along with nearly £4M of investment in a multi-user state-of-the-art laboratory. **Jamieson's** collaboration with Dstl on neurotoxic peptides is currently influencing government policy, leading to further funding. **Thomson** has quickly developed an international reputation for using computational design methods to create new peptide-based structures. He has been awarded an EPSRC first grant and is a Co-I on a cross-research cluster EPSRC grant with **Kadodwala**. The new appointments have complemented existing expertise. In addition, **Hartley** has an international reputation for developing probes to understand oxidative stress and redox signalling, resulting in funding from the BBSRC and Wellcome Trust, high impact publications (*Nature*, 2014 and 2018) and commercialisation partnerships (Cayman Chemical, Abcam, Tocris and Sigma) leading to one of our impact case studies. In the area of synthetic chemistry, **Clark** has been awarded funding (EPSRC and Leverhulme Trust) for the total synthesis of fused polyether, marine natural products.

**Chemical Photonics:** Key achievements include new metamaterials (*Nature Comms*, *JACS*, *ACS Nano* etc), leading to a close link between **Karimullah** and Horiba, substantial funding (including an UKRI EPSRC Innovation Fellowship (**Karimullah**), a Leverhulme Research Fellowship (**Kadodwala**) and an ERC Advanced Fellowship (**Wynne** based on his pioneering liquid work (*Nat. Chem.*, 2016)). A significant fraction of **Chemical Photonics'** funding is derived from bilateral programmes with international bodies (National Science Foundation, Japanese Society for the Promotion of Science). The cluster has been strengthened over the REF period by University investment including laboratory refurbishments (£300k) and new appointments (**Hedley** 2017; **Karimullah** 2018).

**Complex Chemistry:** This cluster aims to define the area of 'chemical informatics' applied to the emergence of life, digitization of chemistry, and the development of chemical computers. The University has invested heavily in digital chemistry (around £5.5M over the last 5 years) with further investment planned. The strategic appointments of **Draper** (configurable materials, a Leverhulme Trust Early Career Fellow), **Vilà-Nadal** (theory), **Parrilla-Gutierrez** (programming) and **Schmidt** (polymer science) were made to provide key skills. The cluster has a prodigious output and has raised significant income (£17.8M over the REF period), including an EPSRC programme grant (led by **Cronin**), funding from DARPA, and funding for an international centre-to-centre grant. DeepMatter, a spin-out company has raised more than £10M to develop digital glassware and now employs over 40 people in Glasgow and Munich. Industrial interactions include more than 25 companies building 'Chemputers', BAE investing in the chemical brain, Johnson Matthey investing in materials discovery and Samsung investing in autonomous digital chemistry.

**Energy Conversion and Storage:** We recognise the growing opportunities in this area and have targeted recruitment to strengthen the area of organic electronics and photonics (**Skabara**, *Acc. Chem. Res.*, 2019) and perovskite-based materials (**Docampo**, *Nature Nano*, 2014). Major grant successes arising from this grouping include a £5.5M EPSRC Programme Grant in Future Manufacturing (led by **Skabara**) that involves, the Universities of Cambridge, Sheffield, Manchester and Strathclyde and 13 companies and research centres, a Royal Society URF Fellowship (**Symes**) and EPSRC SUPERGEN programmes. Funded (H2020, Royal Society, EPSRC, GCRF) international collaborations involve world-leading groups in China, Taiwan, Japan, Brazil, Lithuania, Germany, Portugal, France, Poland, India, South Africa.

**Heterogeneous Catalysis:** This cluster has exceptionally strong links with industrial partners. Over the REF period, members of the cluster have collaborated closely with Sasol Technology (UK) Ltd., Johnson Matthey, Syngenta, Huntsman Polyurethanes and Ineos Chlor. The section has strong links with the recently developed national catalysis consortia of universities, the UK Catalysis Hub; members sit on the Hub Steering group and are involved in several active research projects. **Lennon's** strong industrial links are contributing to two of our impact case studies. In 2019, the cluster, along with two industrial collaborators and a senior Central Facility scientist, launched a postgraduate degree programme in Industrial Heterogeneous Catalysis. Linked to this,

**Gibson** was a strategic appointment as a University-funded Lord Kelvin Adam Smith Fellow owing to her exceptional talent and track record (*Science*, 2017; *Nature Catalysis*, 2019).

**Supramolecular, Electronic and Magnetic Systems:** This new cluster aims to exploit a wide range of molecular- and nano-systems. New appointments were targeted to provide key expertise including **Adams** (supramolecular systems, EPSRC Early Career Fellow 2015-2019), **Farnaby**, (lanthanide and actinide), **Busche** (a Royal Society of Edinburgh Research Fellow in molecular electronics) and **Peveler** (Lord Kelvin Adam Smith Research Fellow in sensing, diagnostics and chemometrics). Key contributions have been made in the areas of supramolecular materials (**Adams**, *Nature Chem* 2015; *JACS* 2018) metal-organic frameworks (**Forgan**, *JACS* 2015, 2019; **Forgan** was awarded an ERC Grant in 2016); single-ion and molecular magnets (**Murrie**, *ACIE* 2019, *Nature Comm* 2016); structure and dynamics of DNA hairpins using single molecule techniques (**Magennis**, *JACS* 2015); transuranic organometallic complexes (**Farnaby**, *Nature Chem.* 2016); molecule-based flash memory (**Busche** *Nature* 2014) and detection of ultra-trace levels of small molecule analytes (**Peveler**, *Nature Comm.* 2016).

**Strategic objectives for the next five years.** The School plans to expand its research activity in line with the above strategic themes. We are proactively seeking new funding opportunities, tackling UKRI Challenge areas and influencing policy. Immediate plans include:

- further enhancing our infrastructure and facilities with on-going investment in the Advanced Research Centre (ARC). The ARC is a university-wide interdisciplinary research building, with investment of some £113M. It is one of the key components of the vision for a modern research-led university, whose focus is on creating a space for radically new research collaborations to flourish. The School's strategy for the forthcoming period is to maximise the current collaborations of **Cronin** and **Jamieson** with other Schools; these two research groups will therefore move to the ARC and co-locate with collaborators having been allocated ~1200 m<sup>2</sup> of space. This will free up significant space in the Joseph Black Building, which will be refurbished to provide key interaction space and allow for expansion of staff in our core research areas.
- building our impact agenda in cases where translation of our research by both established (e.g., **Cronin**, DeepMatter) and new staff (including **Jamieson**, spin-out on antimalarials and **Draper**, smart windows technology) is possible. We will support such success, for example by providing sabbaticals and further investment such as PhD students.
- increasing our significant success with Fellowships to drive opportunities by mentoring potential Fellows at School and College level. Applications are strongly supported by direct contributions of £100k per application by the Lord Kelvin Adam Smith Fellowship Scheme.
- growing our PhD numbers further, particularly improving internationalisation by targeting recruitment fairs and expanding our strategic partnerships with overseas universities.
- further strengthening our equipment base
- further improving our ECR mentoring and our diversity balance (see Section 2).

**Facilitating Impact.** The School has a strategy of strong engagement with industry and elsewhere to maximise impact. However, we recognise that this is an area in need of continuing improvement. To enable this, we actively manage the impact pipeline, with **Hargreaves** (our impact champion) continuously monitoring progress and potential cases within the School. Impact is firmly entrenched in the University's promotion criteria and we will support further opportunities as discussed above. We target specific opportunities, helping direct the allocation of Impact Acceleration Accounts (IAAs) for example, as well as providing aid and advice in interacting with companies. For example, **Jamieson's** work with Dstl was facilitated using an IAA, which allowed a funding gap to be bridged, led directly to a publication (*Chem. Sci.*, 2018) and has now resulted in further funding from Dstl. IAAs have been used successfully by **Adams**, **Cronin**, **Draper**, **France**, **Gregory**, **Jamieson**, **Lennon**, **Skabara** and **Sutherland** in collaboration with companies including Hyaltech Ltd, Johnson Matthey, the NHS and Syngenta. For example, **Draper's** transfer of a key process into Hyaltech Ltd, funded by an EPSRC IAA, was facilitated by a PDRA working at the company. **Jamieson's** IAA with IRIS Biotech has led to a Innovate UK iCURE grant, with



the synthetic output being protected (PCT/EP2019/062862) and subsequently licensed to IRIS Biotech GmbH (Germany). **Skabara's** IAA with Plessey has led to the company funding a collaboration on microLEDs. Overall, IAAs have supported three of our impact case studies.

The School currently has had active links with >85 companies as well as with NGOs and Government labs, and with non-academic NHS staff. For example, the **Heterogeneous Catalysis Cluster** has several key collaborations with a variety of companies who make use of unique facilities such as the bespoke Chemical Process Fundamentals Laboratory (CPFL), which allows handling of hazardous reagents and products such as phosgene. This has led to direct impact as exemplified by our impact case studies. Members of the School make full use of (inter)national and locally available funding to exploit research that has an impact on the economy, society, and developing countries. The School has launched spin-out companies such as DeepMatter (**Cronin**) which aims to digitise chemistry. We also encourage other routes to impact; for example, **Sutherland** in collaboration with GE Healthcare and NHS Scotland has developed a range of novel radioiodination methods that have been used to produce SPECT tracers for the medical imaging of neurological and cardiovascular disease. Further funding from Medical Research Scotland, GE Healthcare, with EPSRC KTA and IAA has resulted in a wide range of general radioiodination methods that are used by NHS Scotland and GE Healthcare. MRC-GCRF funding awarded to **Wynne** was used to develop malaria vector surveillance tools with partners in Tanzania and Burkina Faso.

**Supporting interdisciplinary research.** Research in the School is highly multidisciplinary in nature. There is significant synergistic intra- and inter-cluster research that allows the School to attract significant UKRI funding. For example, several grants held by **Kadodwala** (Chemical Photonics) in the field of metamaterials involve **Laphorn, Cooke** (ECS), **Sutherland** (CB&PS) and **Thomson** (CB&PS). **Cronin's** Programme Grant includes **Adams, Clark** and **Symes**, all from different clusters, with the aim of making and discovering molecules using a chemical programming language that is run in a modular Chemical-Robot. This work demonstrates our approach of combining traditional concepts to provide unique and distinct flavours of chemistry within the School.

Cross-School collaborations are encouraged. In order to foster cross-disciplinary research over this REF period, the Head of School organised research sandpits with colleagues from Physics, Engineering, Cell Engineering and the Institute of Molecular Cell & Systems Biology. Direct output from these sandpits include research proposals (e.g., **France** with Page (College of Medical, Veterinary & Life Sciences - MVLS) and publications (e.g., **Symes** and **France**) and the involvement of Chemistry staff into the Cell Engineering lifeTIME Centre for Doctoral Training (CDT) (e.g., **Draper** is on the CDT Management Team, PhD students awarded to **France** and **Adams**). **Jamieson's** close link with Tobin (MVLS), initially funded by a University cross-discipline PhD studentship has led to a 2019 paper in *Science* and further funding via the Bill and Melinda Gates Foundation. **Kadodwala** has close links with Gadegaard (Engineering), with significant outputs (e.g., *ACS Nano*, 2017; *JACS*, 2018) and joint research income. **Skabara's** EPSRC Programme Grant links to manufacturing, working closely with Dahiya (Engineering). In addition, the School has received 3 Lord Kelvin Adam Smith PhD scholarships, prestigious University-funded studentships designed for cross-disciplinary research, during the REF period. The University supports cross-disciplinary work with direct mechanisms for enhancing and funding interaction; for example, the College has provided **Skabara** with 2.5 PhDs to work with Dahiya (Engineering). A total of 19 PhD students are currently funded between Chemistry and other Schools at UofG.

**Open Research Environment.** We are actively progressing towards an open research environment. The University library supports researchers in making publications and data open access through training, data management plan review and repositories for longer term storage of outputs. The library deposits items in institutional repositories, provides licencing advice, and maximises open access opportunities. The institutional repository and registry can be used for the long-term storage and sharing of data that underpin research publications. We are one of two UK HEIs that are signatories to the Concordat on Open Research Data. UofG has aligned its investment and policies to further a culture that supports integrity. An annual investment of >£800k ensures that research staff and students have access to expertise for designing and sharing

research, mandatory training on good practice for PGRs and ECRs, data storage, expert editorial support for developing publications, and tools for analysing their citation-based performance. In the School, we are developing open research approaches. For example, **Cronin** is using collaborative programming tools to allow chemists and software developers to work in real time to build a programming language for chemical synthesis (*Science*, 2020).

**Research Integrity.** The Research Committee in charge of the topic in the School and we follow UofG processes. UofG's approach to promoting a culture of research integrity through the roles of Integrity Champions and Advisers has been recognised as a beacon of good practice across the sector, and the model is currently being used as a case study for both the UK Research Integrity Office and the Royal Society. Within the School, staff and PGR students have mandatory research integrity training, provided by the University. Case studies for PGRs are tailored to the discipline and positive feedback on what students have done as a result of the training (e.g., discussed issues with their supervisor, signed up for ORCID, etc.). Integrity issues within the School are handled at the Section level in the first instance, with individuals able to talk to their Cluster Head for information and advice. The School has an Ethics Champion (**Cooke**) and the College also has an Integrity Champion (**Hartley**). A logbook of ethical issues that have arisen is produced by **Cooke** and discussed at the annual ethics committee meeting.

## 2. People

### i. Staffing strategy and staff development

The School has expanded and re-focussed over the REF period. A total of 15 new academic appointments have been made with a balance between established senior academics, to provide leadership and mentoring in new research areas as described by the clusters (Section 1) and ECRs to provide a critical mass in identified areas. Of the new appointments, 10 were ECR, bringing us to 24% of our staff being ECRs. We have recruited internationally excellent researchers as part of our strategy to strengthen key areas, allow new areas to be developed, and provide succession planning. For example, **Gibson** was employed with the aim of providing succession planning within the Heterogeneous Catalysis cluster. UofG's Lord Kelvin Adam Smith (LKAS) scheme was introduced in 2012 with the aim of attracting and retaining outstanding researchers as they establish their independent research career in order to attract emerging leaders. This Scheme has been used to support new staff (**Gibson**, **Parrilla-Gutierrez** and **Peveler** are fully funded by LKAS Fellowships), as well as providing a £100k top-up to strengthen Fellowship applications (**Draper** and **Forgan**).

The School adopts a transparent recruitment policy where candidates, prior to being interviewed, are invited to give a presentation open to all staff and students, who are subsequently invited to give feedback on the candidates which is considered by the appointment committee. We believe that staff to input into recruitment decisions is important for the cohesion of the School. The School has a well-documented and effective induction process for all new staff.

Several teaching-only appointments have been made over the period (**Docherty**, **Odedra**, **Watts**, all on permanent contracts) bringing the total number of such posts to 6. This has been done strategically to support research activity, improve the quality of undergraduate teaching, and give R&T staff more time for research. Our Teaching team has developed novel outreach and interface activities with the UofG; the School's Outreach Group was highly commended at the STEM Inspiration Awards at the House of Lords (2019).

Research in the School is comprehensively supported by 18 technicians. We have a strategy of providing technical support in all research laboratories to provide key support ranging from synthesis to running and maintaining equipment and providing long-term consistency of approach. The technical staff are active members of our research groups, for example being co-authors on publications (e.g., **Mclver**, *ACIE*, 2017, **Yu**, *Beilstein J. Org. Chem.*, 2020).

Research Staff (PDRAs) are an important and integral part of the School. UofG is a signatory to the Concordat to Support the Career Development of Researchers. The PDRA staff run their own monthly forum, providing amongst other things careers advice (e.g., career-based talks from an editor from *Nature*, an Anton-Paar sales representative, and a science teacher). These careers talks are open to PhD students and complement a suite of College-wide events (e.g., mock

employer-led interviews) and the dedicated Careers Adviser for researchers, who provides one-to-one and workshop support.

The School encourages continued research activity by Senior Emeritus staff, who have contributed papers, generated research income and provided valuable expertise. For example, **Jarvis** is providing an impact case study on timber growth.

**Career development.** The University offers a wide range of training opportunities for staff through a series of online and physical Continuous Professional Development (CPD) courses, mainly offered via the Human Resources' section for Employee and Organisational Development. The courses include training in professional and organisational development, and IT training, as well as a set of mandatory training courses including health-safety-wellbeing, the General Data Protection Regulation (GDPR), equality and diversity, research integrity, and recruitment and selection.

All staff have a Performance Development Review (PDR) annually. PDRs are based around a Portfolio of Activity that records staff activity and outputs, informs the discussion around workload and career development, and provides evidence for reward or promotion. PDR includes a discussion of strategy, direction, publishing and funding plans; this enables a managed approach to research development aligned with the School's priorities. PDRs identify training and developmental needs that may be preventing an individual from seeking leadership roles, whether academic or outside the sector. Reward and Recognition is directly linked to the PDR for all staff; an exceptional rating results in an automatic increment in salary.

The annual promotion round normally begins each January, with workshops run each December by the Head of School and the College HR director to explain the criteria and provide help throughout the process. Promotion for research and teaching staff is a competitive and well-defined process, requiring demonstration of a significant international research reputation, based on objective criteria and strong external support. In this REF period, **Corr**, **Hargreaves**, **Hartley**, **Kadodwala**, **Lennon** and **Murrie** have been promoted to Chair, **Forgan** to Reader in 2016 and Chair in 2019, **Sutherland** to Reader in 2016 and then Chair in 2020, **Jamieson** to Reader, and **Miras** and **Symes** to Senior Lecturer. Professorial zone movements are also annual and are based on clear criteria.

UofG organises annual Emerging or Aspiring Leaders courses. These help more senior staff to prepare themselves for senior roles in research and/or school management roles, which we have used to help succession planning for major roles in the School and College. Over the period, these have been attended by 8 individuals, including **Cooke** (Head of School for most of the REF period), **Corr**, **Hargreaves** (Head of School from Jan 2021), **Hartley** (became the College Dean of Graduate Studies in 2019) and **Wynne**.

The School takes great pride and care in developing the early career staff and pro-actively supports them in winning personal research fellowships. New Lecturers have reduced lecturing and demonstrating loads to aid with the transition to an independent research career (typically 50%). All new staff receive an institutional induction and training, covering diversity, inclusion, safety, teaching and grant writing. New staff take the University's Early Career Development Programme (ECDP), which supports the development of leadership and team management skills, as well as developing skills to improve individual research performance. **Hartley** is the College ECDP champion. ECDP aims to support newly appointed academics to develop their skills and progress in their career within a defined timescale, through the setting of annual objectives, mentoring, and networking. Tailored learning and development are provided in key areas (Learning and Teaching, Research and Knowledge Exchange and Leadership), aligned to promotion criteria. One of the programme's biggest successes is the number of women who have been promoted in the College. Part of the ECDP course specifically targets development of an EPSRC-style grant application, guided by senior staff and using peer-to-peer review. A reward of £10k is provided for excellent proposals (awarded to **Draper**, **Hedley** and **Thomson**, whose grants were then funded by EPSRC New Investigator Awards and **Farnaby**). The Glasgow Crucible is a leadership and development programme that supports ECRs in taking the next step in their career, with the aim of encouraging researchers to be bolder and more ambitious in their funding applications and publications, to become familiar with the knowledge exchange agenda,

and to develop meaningful collaborations within and outside the Institution. Over this period, **Boyer, Draper, Farnaby** and **Peveler** have attended this course, with **Hedley** attending the Scottish Crucible course.

The School has a formal ECR group that functions through peer support. The Director of Research (**Skabara**) meets with this group bimonthly to offer advice on career progression with an emphasis on research. This includes grant proposal writing, time management, maximising networking opportunities, working in medium-large consortia, and collaborating with industry. The School's ECR Champion (**Farnaby**; this is a new post strategically created in the REF period to give ECRs a voice in decision-making committees) liaises with a College level ECR board and provides direct support such as guidance on the School/College/University Research Support structure to incoming ECRs in the School. ECRs are encouraged to take leadership roles to develop their skills and network. For example, **Symes** is the School's Internationalisation lead, and **Draper** serves as a member of the management group for the lifeTIME Centre for Doctoral Training (led by MVLS). ECRs are represented on Safety, Teaching and Research committees.

Evidence of the success of our approach to nurturing and mentoring ECRs can be found for example in the progression of **Forgan** from Royal Society University Research Fellow, winning an ERC Starter Grant (2016), and being promoted to Reader (2016) and to Professor (2019). **Corr** was hired as a Lecturer in 2013, promoted to Reader in 2016, won multiple grants and was promoted to Professor in 2018 before moving to Sheffield in 2018. **Draper** was awarded a Leverhulme Trust Early Career Fellowship in 2017, a Lectureship in 2018 and an EPSRC New Investigator Award in 2019.

We actively encourage career development for PDRAs and technicians. For example, **McAulay** (PDRA) took part in visNET, an EPSRC-funded Scottish multi-disciplinary network for female staff aiming to remodel the implicit 'rules' of networking and collaboration. **Mcliver** started a PhD in 2020 after 37 years as a technician.

**Mentoring.** The School has a defined mentoring policy for staff to provide significant personalised and career development support, extending the University-wide early-career and professional development schemes, with a transparent policy in place. PDRAs receive mentoring from their PIs, including advice on career progression, and technical feedback on job / fellowship / funding applications. New staff are supported by a studentship and start-up costs, as well as free access to the School's equipment for 3 years in addition to a personal academic mentor from Chemistry to guide their research grant strategy and other aspects of research planning.

We have instigated peer review and feedback of each other's grant applications for both senior staff and ECRs as Director of Research support, leading to an improvement in funding success. Recruitment of senior staff with established track records of research funding act as mentors. Increased networking has helped mentors make new strategic connections for ECR staff and increased participation on funding panels which has helped mentors to develop their grant-writing skills and knowledge of strategic priority areas which has been passed on to mentees. As specific examples, **Kadodwala's** Meta-Smart EPSRC grant was peer-reviewed by **Skabara** and **Adams**, **Draper's** EPSRC NIA was peer-reviewed by **Cronin** and **Skabara**, **Hedley's** EPSRC NIA by **Skabara** and **Kadodwala**, and **Skabara** and **Adams** held a mock panel for **Karimullah's** EPSRC Fellowship. Successful proposals are shared internally.

**Extended Research Leave.** Sabbaticals are encouraged, for example with **Clark** spending 4 months at the University of Sydney and 4 months at ETH Zürich. **Cooke** will be on sabbatical for one year from January 2021. Research staff have spent time at companies to transfer knowledge. For example, **Rossi**, a PDRA working with **Draper** spent 6 months working closely between the School and Hyaltech. We are actively encouraging sabbaticals to enable our impact agenda (see Section 1).

**Equality and Diversity.** The School's Athena SWAN Bronze award was renewed in November 2018. We revamped and expanded the self-assessment team responsible for delivering the action plan and aim to achieve a silver award in the next 3-4 years by maintaining and building upon recent progress in equality and diversity (e.g., our recruitment of both UG and PGR students has reached near gender parity and we are actively working to improve our diversity in other areas) and focussing efforts further on professional and technical staff through, for example, endorsing



and implementing the principles of the UK-wide Technician Commitment. We are aware that we have more to do in this area; for example, only 23% of PDRAs in 2020 are female, and we have been working with HR to revise our job adverts as one means to address this. Our current priority is to improve mentoring. For example, we are setting up peer-mentoring groups for PhD students and a cross-school/college mentoring partnership for technicians.

We have appointed a Welfare Officer (**Prunet**) to give informal confidential advice and support to PGR students, implemented family-friendly working practises, such as policies to allow flexible or part-time working, ensured departmental events take place within core office hours enabling all those with parental or caring responsibilities to attend, and implemented access to the University's Academic Returners Research Support Policy which provides grants to all individuals (women and men) returning after periods of parental or carers' leave to facilitate their return to research. **Corr**, **Draper** and **Gibson** were awarded £10k upon their return to work. The School has a Disability Coordinator (**Jackson**), who is responsible for ensuring that the needs of disabled students and staff are met. The School has enabled students with a range of disabilities to fully engage with teaching (UG and PGR) both in lectures and the laboratories by, for example, modifying fume cupboards to operate with wheelchairs and at variable height and having one-to-one support.

## ii. Research Students

To ensure a dynamic and thriving graduate programme that supports research excellence and establishes the best possible environment for our students, we have implemented several key strategic objectives that include excellence in the recruitment of students and in our research and training provision, internationalisation through student mobility, effective administration and communication that provides supportive infrastructure for students and academic staff. The realisation of these objectives has led to a significant growth in our PGR numbers from 119 in 2013 (REF2014) to 146 in 2020 (44% international students), and we have maintained a high completion rate (average >89% completion on time for PhD students finishing during the REF period), which demonstrates the success of our mentoring and training. In the last three years, the proportion of female PhD students has risen too as a consequence of our renewed focus on Equality, Diversity and Inclusion and the renewal of our Athena Swan Bronze Award. We actively support those needing a flexible approach. For example, we have PGRs who are part time for family reasons and our mandatory PGR Supervisor training provides specific recommendations for how to promote inclusivity in research groups, PGR recruitment and conferences.

PGR students are an integral part of the School's activities and are represented on various committees within the School (Athena Swan, Safety, etc.) and the College, such as the Student Liaison Group (vital for student feedback and facilitates communication of initiatives and opportunities between the PGR convenor and the student body).

We have increased our PGR numbers by targeting more diverse funding sources. Around one third of our studentships are provided through the EPSRC DTG and a College studentship bank (a strategic University fund specific to Chemistry to enable growth). Further studentships are funded by internal competitions such as the College Scholarship, the China Scholarship Council, and Lord Kelvin Adam Smith schemes. Much of the increase in studentship numbers has been through co-funding by industrial partners (including GSK, GE Healthcare, AstraZeneca, Syngenta, Huntsman, and Johnson Matthey; the University matches industrial funding to maximise our industrial engagement), funding from various charities (Cancer Research UK, Leverhulme Trust, Medical Research Scotland, Carnegie Trust, etc.) and through major ERC grants. We also have had Energy Technology Partnership (ETP) funded studentships where Industry and ETP contribute most of the funding e.g., **Cooke** (Merck). The School is involved in the EPSRC-funded CDTs in Intelligent Sensing and Measurement and in Engineered Tissues for Discovery, Industry and Medicine (lifeTIME). We are developing PhD programme partnerships with Universities and Research Institutes in China (Nankai University and Beijing University of Chemical Technology) and applications for Commonwealth funding to support PhD placements from India are also actively promoted. Applications from fully funded international students form part of our targeted growth strategy.

**Approach to PGR recruitment.** Effective recruitment of high-quality students has been achieved through a college centralised marketing policy. Studentships are advertised on the web and via social media. Entry to PhD requires a research Masters degree, or a 1<sup>st</sup> or 2.1 Honours degree (or

equivalent) in Chemistry or appropriate related discipline. Applications are rapidly disseminated to the appropriate supervisor for assessment to ensure recruitment of the best candidates. Applicants are assessed by reference and prior academic achievement, and then interviewed by a selection committee including the potential supervisors. The School aims to make a decision within one month of receiving an application. Retention of outstanding undergraduates is encouraged by PhD information sessions early in the final year of their degree. We have been extremely successful with highly competitive Carnegie Trust studentships, which are only awarded to students achieving a high 1<sup>st</sup>, allowing us to retain many of our best students. To encourage international applications, financial support has been provided for academic staff to carry out lecture tours and raise awareness of the School in Central and Southern America (Science without Borders, COLCIENCIAS and CONACYT), the Middle East and Northern Africa, leading to direct recruitment.

**Progress Monitoring and support mechanisms.** A system of dual supervision, and the involvement of an additional member of staff as an assessor in the annual progression reviews means that all aspects of the quality of each student's work are evaluated and that each student's specific developmental needs are addressed. The cluster head is involved in the assessment of each student in their cluster to ensure consistency in approach and standards. This structure provides multiple points of contact within the School if the need arises. At the outset of their studies, PGRs are informed about the context of the training environment and how they can use the Researcher Development Framework (see below) to ensure they develop skills in the range of areas required to support their professional and career development. This is monitored for each student with an individual training needs analysis form that is discussed annually at progression to ensure key skills are being developed. Progress monitoring occurs in Year 1 and Year 2 progression meetings, requiring a written report and a detailed viva by two staff. A thesis plan is written at the beginning of Year 3; our careful support and monitoring has ensured an excellent completion rate (>89%).

**Skills Development and Training.** The development and training of our PhD cohort is central to our strategy for PGR excellence. All PGRs are part of the CoSE Graduate School, a large graduate school (~890 PGRs and ~1000 PGTs). The Science and Engineering focus of the Graduate School allows specific relevant training for the cohort.

Students are enrolled in the CoSE Doctoral Researcher Training Programme which has a range of courses that complement their research and develop transferable skills. We require that 4 of their 14 necessary credits come from internal Chemistry courses which include lectures and practical training in addition to mandatory safety training. We provide mandatory face-to-face integrity and data management training to all PGRs. The programme is aligned with the Researcher Development Framework and includes leadership, project management and presenting with impact, data visualisation and animations, and public engagement internships. This training has evolved to include online modules, webinars (to accommodate students based off-campus or with limited accessibility), and discipline-specific content. We are passionate about fostering a research community and culture amongst our PGR students; the programme includes competitions (3-minute thesis, impact in 60 seconds, Science Slam), a PGR-led blog and other community building initiatives and opportunities to network with industry, as well as accredited and short courses. Our students regularly organise and participate in Glasgow's Pint of Science. These activities are supplemented by research networking, and social events within the school, e.g., through the Alchemists Society (the School's extremely active PGR-led society).

All PGRs are required to attend research colloquia in their cluster area, as well as School Research Seminars (approximately 22 per year).

Mental health and well-being are recognised as a general area of concern for PhD students. An environment conducive to good student well-being and mental health has been created through the communication of various counselling and psychological services at induction sessions, as well as training for staff on recognising and addressing potential issues and a variety of well-being support ranging from sessions on 'getting a good night's sleep' or 'managing perfectionism' to PGR gardening and lunchtime walks. Supervisors are supported through development workshops, to ensure consistency and to raise awareness of regulations and codes of practice. The CoSE Graduate School in conjunction with our PGR convenor and PGR committee is proactive in

developing a culture of equality and diversity in which training is compulsory for both supervisors and PGR students.

All students are trained and mentored to produce high quality publications, as well as to present their work internationally. Our recruitment strategies have allowed the growth of PGR numbers while maintaining the high standard of research, as evidenced by the strong contribution of PGR research to this REF submission. PGRs can apply for School funds for international travel; we actively monitor the gender distribution of these awards. In this REF period, 46 students have benefitted from this, attending conferences across the world. CoSE funding is available for international mobility internships (1-3 months), allowing PhD students to develop new complementary research skills. Several PhD students have spent time at companies or with collaborators. For example, **McGuire** spent 3 months at Tulane University, New Orleans with Professor Donahue to prepare new multiple centre electron-spin qubits. **Dos Santos** spent one month at KAUST testing new molecules in organic solar cells and developing device fabrication skills. **Gottardi** carried out multiple 3-9 day visits at Merck fabricating several hundred test-scale organic solar cells. **Lomax** has been on secondment to the European Space Technology Centre in the Netherlands.

The quality of our research students is clearly evidenced by their considerable success in gaining external recognition with various awards and prizes. Two exemplars of success are **Cross** as 1<sup>st</sup> place PhD student in the ABTA Doctoral Research Awards 2019: Science and Engineering (2019), as well as winning best oral presentation at the RSC Scotland and Northern England Electrochemistry symposium (Butler meeting) in 2019 and **Poya** who was awarded 1st place in the highly competitive 2019 SCI Scotland PhD student competition and selected to participate in the highly competitive Green Talents programme. We are proud of our successes, and these are disseminated to the College by a regular newsletter.

In summary, we have many successes of which to be proud. Glasgow PhD students were co-authors on ~48% of REF-eligible outputs in 2019, average >89% completed on time, and graduating PGRs from the school are highly sought after and find employment in a variety of roles in academia, industry, government and charities. A recent snapshot of students graduating in 2020 showed 43% progressing to an academic PDRA, and 40% to industry/government R&D.

### 3. Income, infrastructure and facilities

**Research Funding.** Our growth and success have been achieved by a deliberate focus by the School on improving and diversifying income, increasing the number of grant holders, and a policy of hiring high-quality staff. We have targeted mentoring to achieve internationally recognised Fellowships and we have set up multidisciplinary research clusters to enable large grant applications. We also recognise that industrial links and smaller grants are equally important. This has included senior staff with established records, as well as ECR staff with high potential. This potential has been realised (e.g., with **Draper, Hedley, Thomson** all awarded EPSRC New Investigator Awards). We have been aided by a dedicated Project Coordinator providing cradle-to-grave support of grant management, as well as a dedicated Research Support Administrator. A dedicated College Research Development Manager provides College research support in Chemistry, e.g., assisting with funding applications, coordinating cross-College applications, contributing to ECR grant writing workshops etc.

Since the last REF, there has been exceptionally strong funding generated across the School, emphasising our nationally and internationally leading activities. As specific examples, Complex Chemistry is backed by an EPSRC Programme Grant (which also involves individuals from other clusters), funding from DARPA (four separate grants), funding for an international centre-to-centre grant as well as a Platform Grant (**Cronin** PI, with **Vila-Nadal** as ECR co-I). This has enabled the development of the ChemPuter for example (*Science*, 2019). We have several examples where senior academics have successfully collaborated with ECRs, including for example **Kadodwala's** EPSRC grant with **Thomson**. Major multidisciplinary manufacturing projects are led by **Skabara** through a Programme Grant (£5.5M) and a Platform Grant (£1.29M). **Hartley** is the chemical core of a multi-centre, multi-disciplinary team focussed on oxidative stress and redox signalling, particularly from the mitochondria, publishing with researchers in 15 different countries. His long-term collaboration with Murphy (Cambridge, *Nature* 2014), is backed up with a Wellcome Trust

Investigator grant. **Hartley's** molecular probes are marketed world-wide by companies that specialise in biomedical research including Cayman Chemical, Abcam, Tocris and Sigma, leading to one of our impact case studies. **Kadodwala** is a member of a major (ca. £100M over 10 years) Japanese research initiative, a World Premier Institute in Chirality, which is based at the University of Hiroshima. **Kadodwala** in collaboration with Horiba Corp, a major scientific instrument manufacturer, has received financial support from the EPSRC-funded UK Quantum Technology Hub in Quantum Enhanced Imaging to establish the feasibility of developing an early-stage sensing technology for future commercialisation. This led to **Karimullah** being awarded a UKRI EPSRC Innovation Fellowship to commercialise aspects of this work. **Cronin, Forgan and Wynne** have all been awarded European Research Council (ERC) grants in the REF period. **Adams** held an EPSRC Fellowship during the REF period, and **Kadodwala** was awarded a Leverhulme Trust Fellowship.

**Infrastructure developments.** The University is currently undergoing significant investment in its estate (£1B). The School's success in developing infrastructure and facilities that support our strategic aims and underpin our research activity has been enabled by substantial University and external investment. This has resulted in an expansion of our research laboratories and equipment base. We have focussed on developing facilities that can help us to deliver research excellence. Developments have included:

- £16.6M investment in the School, including refurbishment of our Grade 1 listed building. This includes newly refurbished laboratories within the School, providing state-of-the-art research facilities for wet chemistry and laser and microscopy laboratories, refurbished library and study space, and new kitchen facilities. Lab refurbishment for **Skabara** starts in January 2021 (delayed due to COVID-19).
- The ARC will open in 2021 and is located on the existing West End campus. The ARC will create a collaborative environment to attract, stimulate and enable interdisciplinary research, and will be the focus for researchers across the University to collaborate and interface with partners from outside the University. **Cronin** and **Jamieson** will move to the ARC, constituting a direct £3.6M investment supporting our research. These moves, along with Forensic Science moving out of Chemistry, will liberate significant new space within our building (~1010 m<sup>2</sup>). We will use this space to generate new social space to encourage further networking and School cohesion, as well as to allow for the forecasted further expansion of the School through Fellowships, increased PGR and PDRA numbers, as well as generating a new bespoke analytical centre.
- Key donations, showing evidence of the external appreciation of our research strategy and capacity to deliver research excellence, two of which were for the Joseph Black Building infrastructure (£1,855,866 from Martin Bequest, £71,285 from McLean Bequest), as well as a donation for a studentship (£62,317 from the Ian Sword Studentship fund).

The School has a strong base of shared facilities, including:

- Significant NMR provision including four solution state spectrometers with automated sample changers capable of a wide range of NMR experiments and techniques. In 2016, the School's NMR provision was upgraded with a Bruker 600 MHz NMR instrument, with an in-line flow loop that allows it to be interfaced with automated platforms. The NMR service is supported by a dedicated specialist technician.
- Single crystal diffractometer and powder X-ray diffraction facilities. Many of our researchers are reliant on diffraction; during this REF period, we have upgraded our provision, for example by the purchase of a rotating anode Rigaku diffractometer. Our facilities are maintained and run by a dedicated crystallographer.
- A range of analysis facilities including microanalysis (upgraded 2016), supported by one technician, environmental analysis by atomic absorption, pH, conductivity, chloride content, HPLC and GC (one technician), Confocal Raman microscopy using a Jobin Yvon LabRAM HR system with excitation lasers at 532 and 325 nm, Synapse CCD detection system, and Linkam



TS 1000 High Temperature Stage (one technician), mass spectrometry (upgraded with a new microTOFq and electrospray over the REF period) supported by two technicians.

- Scanning electron microscopy, supported by one technician.
- Quantum Design MPMS3 Evercool SQUID magnetometer, installed August 2019.
- A Bruker ELEXSYS E500 EPR operating at X-band.
- Full glassblowing workshop (recently augmented with a second glassblower).

There is also significant specialist instrumentation maintained by individual research clusters accessible either to trained users or through collaboration. In addition, staff regularly make use of other University facilities. These include the state-of-the-art James Watt Nanofabrication Facility (JWNC), which houses over £37M of nanofabrication tools in a 1350 m<sup>2</sup> clean room. This facility underpins key work in the School, particularly that of the Chemical Photonics cluster by **Kadodwala** and **Karimullah**.

We have been particularly successful securing funding to access central UKRI facilities after competitive review; X-ray and neutron scattering experiments have been performed at Diamond, ISIS, ESRF, ILL, NIST and Elletrea (398 days).

We use our facilities to deliver impact. For example, the Heterogeneous Catalysis Section has several key collaborations with a variety of companies who make use of unique facilities such as the bespoke Chemical Process Fundamentals Laboratory (CPFL), which allows handling hazardous reagents and products such as phosgene. The CPFL was commissioned in 2010 and is a manifestation of mature academic/industrial partnerships. Over this REF period, the initiative was promoted further by the School of Chemistry and the College of Science and Engineering to encourage our impact agenda, with direct financial support from two chemical companies: Huntsman Polyurethanes and Syngenta, who are partners in two of our impact case studies.

The University strongly supports computational research through continual investment in computer clusters. The School has a local computer cluster, which was upgraded in 2019 to a total of 250 cores and 1.8 TB of memory. CoSE has recently upgraded its facilities; in 2019, CoSE invested in a shared computer facility providing ~600 CPU cores with 3.5 TB of memory and 20 GPU units with 87k GPU cores. At a University level, a High-Performance Computer (HPC) facility is available as a central University resource for research and teaching purposes (~1200 cores, ~8 TB of RAM, and 8 GPU units). Chemistry make regular and substantial use of the HPC, enabling research projects by undergraduates, postgraduates, and staff who require computational resources beyond that available locally. The University is a partner institution of ARCHIE-WeST, the regional supercomputer centre hosted by the University of Strathclyde in Glasgow. ARCHIE-WeST was established in 2012 with EPSRC e-Infrastructure funds and upgraded in 2018. It provides ~2600 cores and 15 TB of memory.

Continued Library investment during the REF period means that electronic access to >600 chemistry journals (including all ACS journals and a Gold level open access RSC subscription), thousands of scientific texts and access to online databases (e.g., SciFinder Scholar, Reaxys, Scopus, Web of Science) is available to enable our research.

Our future funding strategy will build on the enhancement in our infrastructure and facilities achieved during this period and will focus on research themes highlighted in Section 1. In particular, we will exploit the new opportunities for collaboration presented by the ARC. Examples in place already include the collaboration between **Jamieson** and Tobin which has led to a recent paper in *Science*. As detailed in Section 1, we intend to also focus heavily on our impact agenda.

#### **4. Collaboration and contribution to the research base, economy and society**

The School's activity is based on interdisciplinary and collaborative research, with engagement nationally and internationally with both academia and industry on several levels, from leading large international research networks and projects through to individual collaborations with high-profile academics and industry.

**Academic Collaborations.** Extensive successful academic collaborations exist. International academic collaborations are supported by the University's Internationalisation policy, for example

with travel grants (see Section 2). The School supports external links with joint students (e.g., **Adams** has a PhD student joint with Edinburgh), by prioritising matched collaborations with industry for support, and by providing sabbaticals. Inter-departmental collaborations are promoted by the University's Lord Kelvin Adam Smith (LKAS) studentships, which explicitly require collaboration across Schools within the College (e.g., **Wynne's** work on "Machine learning in spectroscopy", analysing mid-IR spectra of mosquitoes using machine and deep learning to determine species, age, and other properties). In this period, staff have been involved in 7 EPSRC Programme grants, collaborating with academics across the UK. We lead and participate in 12 European networks as well as numerous international networks. For example, **Cronin** has active DARPA grants with collaborators in Canada, the US and South Korea developing systems for the exploration of chemical space.

Examples and evidence of interdisciplinary and international activities include:

- a significant number of the papers published in the REF period have a non-Glasgow author and non-UK based authors. For example, for papers published in 2019, 71% had a non-Glasgow author and 48% a non-UK based author. As a specific example, **Docampo** has long-standing and very fruitful collaborations (Bein & Hartschuh, Munich; Dyakonov, Wurzburg) with funding from the German Ministry for Research and Education leading to many outputs (e.g., *Adv. Energy Mater.*, 2018; *ACS Nano* 2016).
- leading roles in international networks, including for example **Skabara's** links on a FP7 PIRSES, H2020 ITN grant and two H2020 RISE grants.
- the EPSRC funded programme grants of **Cronin** and **Skabara** to develop a 'Universal Chemical Synthesis Machine' and transfer-printing for heterogeneous integration in manufacturing, respectively, as well as **Cronin's** EPSRC Platform Grant to develop Complex Chemical Systems Platform Exploring Inorganic Intelligence and **Skabara's** Platform Grant to prepare next generation processing of photonic devices.
- **Cronin** is part of the NFOLD NASA network, aiming to detect extra-terrestrial life.
- **Kadodwala's** collaboration with Govorov (Ohio University) has led to the development of new metamaterials (*Nat. Comm.*, 2016; *ACS Photonics*, 2018); Govorov is a partner on EPSRC funded project. **Kadodwala** was also a JSPS Visiting Professor (with Okamoto at Okazaki, 2015), leading to a consortium grant (EP/M024423/1), and his Leverhulme Research Fellowship enabled a collaboration with Tagowa (Osaka, 2018).
- **Cooke** has been involved in an ongoing successful collaboration with Rotello (University of Massachusetts at Amherst) since 1997. This collaboration has resulted in 73 joint papers. The work has been supported by EPSRC (£1.4M, EP/I00243X/1, EP/K034936/1) through the EPSRC/NSF funding partnership. The collaboration has widened to include **Kadodwala** and Samuel (St Andrews).
- **Forgan** is part of the EPSRC IRC in Targeting Hard to Treat Cancer (£10M funding for 6 years), a collection of materials scientists, cancer biologists, clinicians and surgeons seeking to develop new targeted treatments for pancreatic cancer, glioblastoma and mesothelioma.
- **Hartley's** group have helped elucidate the biological mechanisms responsible for reperfusion injury following a heart attack as part of his long-term collaboration with Michael Murphy (Cambridge, *Nature* 2014). In a close collaboration with Prof. Luke O'Neill (Trinity College Dublin), RCH developed cell-permeable 4-noctyl itaconate to help demonstrate a key negative feedback antioxidant mechanism in macrophages involved in inflammation, linking the Krebs cycle with the anti-inflammatory response (*Nature* 2018). The wider collaborative circle involved 13 institutes including Harvard and John Hopkins University in the USA, and GSK sites in more than one country.

**Industrial Collaborations.** Over the REF period, the School has been working on how we maximise impact (see Section 1). Focussed industrial projects span a wide range of topics, including a number of active collaborations with companies in the Heterogeneous Catalysis cluster (**Lennon, Gibson, Hargreaves, Jackson**; see Section 1), materials for ocular surgery (Hyaltech, **Draper**), spinouts such as DeepMatter (**Cronin**), links with NASA (**Cronin**) and links with Plessey

(**Skabara**). **Gregory** has joint patents with Airbus Group. Several companies make use of facilities such as the bespoke Chemical Process Fundamentals Laboratory (CPFL), which has led to two of our impact cases. **Köhnke** is a named inventor in several patents that form a chunk of the IP foundation of Gyreox Therapeutics, which just received seed funding. Spray Solutions Co are funding a project based on the work of **Peveler** in collaboration with Clark (Engineering), to develop a proof-of-concept device. **Sutherland** has a long running collaboration with Molecular NeuroImaging LLC (recently bought by inviCRO), a medical imaging company based in New Haven, Connecticut to develop new PET imaging agents for inflammation associated with brain tumours. The ChemPuter (developed by **Cronin**, *Science*, 2019) is now in place in 25 different organisations including GSK; it is attracting funding from a range of companies including Google and has been awarded a NIH grant for a drug discovery challenge (**Cronin** and **Vila-Nadal**).

**Engagement with the Wider Community.** In terms of wider contributions to the economy and society, examples include **Wynne** being awarded an MRC grant to study malaria-carrying mosquitos using infrared spectroscopy and neural-network data analysis, installing equipment and know-how in Tanzania. **Symes** worked with researchers in India on membrane electrolyzers funded via the GCRF. By attending a Royal Society workshop in Kumasi, Ghana, **Skabara** established a link with the Chemistry Department at the University of Ghana. This led to a capacity building Leverhulme/Royal Society Africa Award (2014-2018), involving training of researchers in Ghana at Masters and PhD level, staff and student secondments to Glasgow and establishing an equipment base in Ghana for materials characterisation. We have engaged with the local community through activities such as Pint of Science, visits to local schools and presentations at Science fairs.

Academics within the School actively take leadership roles within the community thereby contributing to the health and sustainability of the discipline, as evidenced through:

- Organising, chairing and co-chairing of high-profile international conferences and meetings including for example MC14 (**Adams**, 2016), MC15 (**Forgan**, 2018), Electrochem2019 (**Symes**, 2019) and Time-Resolved Vibrational Spectroscopy (**Wynne**, 2017).
- Delivering 87 Plenary and >330 invited lectures at international conferences, as well as > 335 invited colloquia.
- **Draپر** sits on the Women in Supramolecular Chemistry (WISC) committee. She has set up mentoring groups and a Parents Cluster group to support marginalised groups working in supramolecular chemistry.
- Acting as advisors to the academic community. Staff act as panel members and Chairs for a wide number of UK and overseas funding programmes and facilities access, including for example **Skabara** as member of 3 Portuguese national panels (including 1 as Chair), 1 TUBITAK research panel for fellowships and currently a member of the Royal Society Research Appointment Panel A(ii); Scientific Advisory Committees, **Hargreaves** as Chair of Panel 5, Diamond Synchrotron Access Panel (2018-2019; panel member 2015-2019); **Gregory** as Chair of Panel 9, Diamond Synchrotron Access Panel (2018-2019); **Lennon** as a member of Oak Ridge National Laboratory's Neutron Sciences Directorate, Spallation Neutron Source, Chemical Spectroscopy Committee (2017-2020) and member of the Chemistry Facility Access Panel for Institut Laue-Langevin, Grenoble, Subcommittee 7, Spectroscopy in Solid State Physics (2017-2019).
- Glasgow Chemistry PIs act or have acted as editors, board members, associate editors and editorial board members of many international journals, for example *Journal of the American Chemical Society* (**Wynne**), *Applied Catalysis A* (**Hargreaves**), *Journal of Materials Chemistry A* (**Cooke**) *Journal of Materials Chemistry C* (**Skabara**) leading to membership of the Royal Society of Chemistry's Publishing Board and its Science & Publications Committee which oversee the publishing strategy of the RSC, *Inorganics* (**Gregory**), *Biopolymers* (**Jamieson**), *Gels* (**Adams**). Many staff sit on Editorial boards including *Scientific Reports* (**Cronin**, **Ganin**, **Symes**), *Catalysis*, *Structure & Reactivity* (**Gibson**), *Chemical Physics* (**Wynne**), and Editorial Advisory Boards including *Chemical Science* and *Chemical Society Reviews* (**Adams**), *Organic Letters* (**Prunet**). Our staff regularly referee for a range of journals

and funding bodies. For example, three staff (**Adams**, **Miras**, **Schmidt**) were in the top 10 reviewers for Chemistry (Publons, 2019).

- Holding visiting Professorships at several international institutions including University of Sydney (**Clark**, who was also the Ernest Ritchie Memorial Lecturer), Kyushu University (**Gregory**), ETH Zurich (**Clark**), University of Nagoya (**Skabara**), Zhejiang University of Technology (**Gregory**), Inner Mongolia University (**Jackson**). Additionally, a significant number of staff (around 25%) hold (or have held) competitively-won Fellowships in the REF period including **Adams** (EPSRC Early Career Fellowship); **Boyer** (Royal Society Fellowship); **Busche** (Royal Society of Edinburgh Fellow); **Cronin** (ERC Advanced Grant); **Draper** (Leverhulme Trust Early Career Fellowship); **Forgan** (Royal Society Fellowship and ERC Starter Grant); **Gibson** (LKAS Fellow); **Kadodwala** (Leverhulme Trust Research Fellowship); **Karimullah** (EPSRC UKRI Innovation Fellowship); **Peveler** (LKAS Fellow); **Symes** (Royal Society Fellowship); **Wynne** (ERC Advanced Grant).
- Contributing to a range of committees and special interest groups, such as Secretary for Macro Group UK (**Adams**, until 2016), Elected member of the RSC Materials Divisional Council (**Cooke**, 2015-2018), Treasurer and founding member of the RSC Interest Group in Porous Materials (**Forgan**), Treasurer of the RSC Surface Reactivity & Catalysis Interest Group (**Gibson**), Chair of the Surface Reactivity and Catalysis Interest Group (**Hargreaves**), Elected Member of the Chemistry Biology Interface Council (**Hartley**), Chair of the RSC Chemical Biology and Bioorganic Group (**Jamieson**), RSC ESR Spectroscopy Group (**Sproules**), Secretary of the RSC Electrochemistry interest group (**Symes**).

The contribution of the School to the community has been recognised through a number of awards and medals in the REF period including: **Adams**, Macrocyclic and Supramolecular Group Prize (the Bob Hay lectureship, 2015); Macro Group UK Award for Contribution to UK Polymer Science (2015); Top Cited ISI (2018); **Clark**, RSC Bader Award (2015); **Cronin**, RSC Tilden Prize (2015); RSC Interdisciplinary Prize (2018); ACS Inorganic Lectureship (2018); **Docampo**, Top Cited ISI (2018); **Draper**, RSC Macrocyclic and Supramolecular Chemistry PhD Prize (2016); BTM Willis Prize (2020); **Forgan**, Sessler Early Career Researcher Award (2018); **Gregory**, IOM3 Kroll Prize and Award (2019); **Schmidt**, Polymers 2020 Young Investigator Award (2020); **Skabara**, Peter Day Award (2018); Royal Society Wolfson Research Merit Award holder (2014-2018); **Wynne**, RSC Chemical Dynamics Award (2018). On top of this, staff were elected to the Royal Society of Edinburgh over the REF period (**Adams** in 2019, **Wynne** in 2015) and **Adams** was elected as a Fellow of Learned Society of Wales in 2018.