

<b>Institution: University of Bradford</b>
<b>Unit of Assessment: B8 Chemistry</b>
<b>1. Unit context and structure, research and impact strategy</b>
<b>Unit context and structure</b>
<p>Chemistry at Bradford has a long history with roots in the industrial revolution as a founding department (Department of Chemistry and Dyeing) of the Bradford Technical College (1882). Chemical research at Bradford has historically focused on technology and modern applications. Following a period of mainly teaching activity in the 1990s and 2000s, Chemistry was re-constructed during the REF2021 period resulting in the first submission to the Chemistry UoA since the first RAE in 1996. From RAE1996 up to and including REF2014, individual chemists were submitted as part of UoA3.</p> <p>The University sits within a significant and dynamic hub of the UK chemicals industry and, from 2014 onwards, the University has invested significantly in Chemistry. The aim was to build all aspects of chemical and biochemical activity (research, innovation and teaching) to maximise the University's contribution to the success of the region on the national and international stages. Within this context our research aims were set after REF2014 and the School has taken this opportunity to craft its research to address the key issues/priorities of the 21<sup>st</sup> century. Following appointment of a new Head of School (HoS, Rimmer) in 2015, all recruitment activities have focused on high-potential early career staff (which has led to a complement of 19 staff with significant responsibility for research mainly recruited between 2015 and 2020). The School aims to be one of the UK's sources of the next generation of academic leaders in Chemistry and Biosciences. Rimmer's term of office has recently finished and a new HoS is being recruited (details in Section 2).</p> <p>Chemistry at Bradford is positioned within a larger School of Chemistry and Biosciences (49 FTE academic staff). The combined School was established in 2016 by merging the School of Biomedical Sciences and the School of Chemistry and Forensic Sciences. The Chemistry (<i>i.e.</i> UoA B8) staff operate within this combined School and are integrated into two clusters, established in 2017: Materials Chemistry (MC, led by Hickey; 10 staff) and Chemical &amp; Structural Biology (CSB, led by Barry, nine staff).</p> <p>The two clusters include the key chemical expertise sets in modern chemical research activity: synthesis, analysis, theory and computation. Our underpinning ethos is to provide the breadth of expertise required to deliver academic excellence, as well as impact outside academia, in these two key interdisciplinary focus areas. This is supported by building and maintaining strong interactions between the two units and other activities at Bradford and beyond. The Chemistry clusters make substantial contributions to each of the University of Bradford overarching research themes: Advanced Healthcare, Innovative Engineering, and Sustainable Societies (see Institutional Environment Statement). Our clusters are broad-based units that will grow and adapt over the coming years. Currently MC enjoys strengths in the synthesis and properties of functional polymers and biomaterials, nanomaterials, supramolecular materials, crystal engineering, and materials computation. Much of the work is directed towards medical applications but we also aim to develop our current work around materials for clean energy. CSB has major strengths in bio-inorganic chemistry, protein/peptide structure and function, biotransformations/biosources of chemicals, biomimetics and computational methodology. Recently this cluster has been strengthened by two appointments in bio-organic chemistry, which completes a broad-based unit covering all aspects of the interface of chemistry with the life sciences.</p> <p>The juxtaposition of the biosciences with chemistry naturally drives a large proportion of the research agenda within chemistry towards the life sciences. The development of such a significant strength in chemistry is not only influencing biosciences at Bradford but is also closely aligned to newly formed clusters in Physiology and Metabolism and Microbiology within the</p>

combined School (for example, much of the work carried out by Rimmer is directed at the synthesis and properties of new polymers targeted at detecting bacteria).

The research activity of the School is guided by the School Research Committee (SRC). The SRC is chaired by the Director of Research (Hickey) and identifies strategic opportunities and initiatives including pathways to impact for the School's research, oversees their implementation, monitors the progression of postgraduate researchers (PGRs) and continually evaluates key performance indicators including grant successes and outputs. The SRC includes a representative from each of the clusters, the Postgraduate Research Tutor, and a representative from the School's Impact Strategy Group for knowledge translation strategy. It meets monthly and reports to the School Executive. The School Executive is chaired by the HoS and includes the Director of Research and the Director of Board of Studies; amongst other things it manages the division of time for staff between research, teaching and administration. The research activities of the School are reported to the Faculty by the Director of Research through the Faculty Research Committee, which then reports to the University Research and Knowledge Transfer Strategy Committee and serves as a conduit for exchange of information and for development and implementation of University's research strategy.

Chemical research at Bradford is supported by excellent facilities for analytical sciences (the Analytical Centre (AC); see Section 3 "Infrastructure and facilities" for details). Chemistry also benefits greatly from opportunities provided by The Polymer Interdisciplinary Research Centre (Polymer IRC) shared with the Faculty of Engineering and Informatics; The Institute of Cancer Therapeutics (ICT) and the Centre for Skin Sciences, both in the Faculty of Life Sciences. The Polymer IRC is one of the UK's largest single-university networks of polymer science and engineering research groups, with the subject having a long history at Bradford dating back to the granting of the University's charter in the 1960s. The ICT is a significant facility, which is a nationally important institution within the UK cancer technologies sphere and is one of only a few centres nationally with the facilities and research expertise to take anti-cancer medicines and biomarkers from concept to clinic. Aspects of strategy have already been formulated to maximise synergies with these centres of excellence (for example, preclinical evaluations of inorganic drug candidates have been published by Barry in collaboration with the ICT, with financial support from the University).

The period since REF2014 has been a period of very substantial success with significant publication and impact profiles, which gives us great confidence for sustainability in the 2020s and which will act as a springboard for the next decade.

### **Research and impact strategy**

The city of Bradford and its surrounding area have a strong chemical industry fabric and our ambition is to combine the very best in chemical research with industrial partnerships to address some of our biggest global issues (for example treatment of cancer and antimicrobial resistance). Our two research clusters enjoy close interactions with translational teams in Health (e.g., in the area of antimicrobial resistance with staff in Pharmacy, Nursing and Midwifery), with the ICT (as exemplified by Barry's work) and with Polymer IRC. Therefore, delivering impact *via* translation is an integral part of our research activity. For example, GrowMedTech recently awarded Katsikogianni, Rimmer and Swift funds to scale up the production of polymers for detecting infection and to initiate engagement with patients in collaboration with the School of Nursing and Midwifery (Faculty of Health Studies). In our health-focused work, we are keen to innovate, encourage, and produce impact using the University's strong interactions with the NHS (see institutional-level statement) in a 'bench-to-bedside-to-community' approach to research. Good examples of this approach include the use of functional materials to detect pathogens and treat wounds, which are being translated into clinical use in strong collaboration with teams from nursing and midwifery, see section 3 for grant details.

The primary strategic aims are:

1. To further the progress of core and fundamental knowledge in synthetic chemistry, computational chemistry and structural chemistry in the contexts of Materials and the Biosciences.
2. To actively promote multi-disciplinarity and overlaps between core disciplines (e.g., Chemistry with Biology, Materials, Engineering) to address major global issues (e.g., cancer, antimicrobial resistance, plastic waste).
3. To use these advances to deliver impact in healthcare, energy and the environment
4. To ensure research sustainability.

**Specific objectives for 2021-2027**

1. To consolidate our research teams through the recruitment of outstanding PhD candidates, post-doctoral research assistants and highly qualified technical staff. The University is highly supportive of Chemistry and we have already achieved substantial success in securing fully funded PhD scholarships *via* the Research and Development Fund (two successful applications from Chemistry in May 2019 out of the four offered). In the last round of faculty PGR Scholarships for Early Career Researchers 2020, three of five PhD scholarships were awarded to the School, two within Chemistry. We will also aim to establish a Centre for Doctoral Training at the interface of Chemistry, Materials, and the Biosciences.

Applications to individual fellowships such as UKRI Future Leader Fellowships and Royal Society University Research Fellowships are strongly encouraged by the School in order to consolidate and expand research teams (see Section 4 for previous successes).

2. To recruit new academic staff in line with the requirements of our two clusters, either to fill gaps in emerging and innovative areas (e.g., recent employment of Crawford in mechanochemistry) or to strengthen one of our existing areas of expertise (e.g., recent employment of Pitto-Barry in bio-inorganic chemistry). Our staffing strategy is detailed in Section 2.
3. To achieve a strong portfolio of research funding, building on our strengths, *via* writing retreats, research away-days focusing on interdisciplinary research and brainstorming of ideas between our two clusters, internal one-day thematic symposia and internal communication. Our strategy is to ensure that every member of the Chemistry staff is aware of the skills and expertise of the others, as well as the research conducted in every research group. Section 3 "Strategy to increase funding income in 2021-2027" contains specifics on this strategy. Our multidisciplinary approach to both fundamental and impact-focused work allows us to apply for funding from a range of potential funders: research councils, overseas aid, industry and charities.
4. To strengthen our partnerships with centres of excellence hosted at Bradford. One objective is to maximise our existing collaborations with the ICT, in order to support the preclinical development of the most promising molecules designed as anticancer drug candidates in Chemistry. We aim to make such progress easier and more accessible for all our staff involved in health research, by organising joint seminars and thematic symposia, with the aim of developing a "bench-to-bedside" translational approach.
5. To develop and maintain research partnerships with institutions in India and in China. The School of Chemistry and Biosciences has established several international collaborations particularly with Asia and the Middle East. For example, Rimmer's collaboration with LV Prasad on antimicrobial resistance has led to novel functional polymers being progressed to animal trials. This work is currently being extended by several Indian colleagues (mainly into the detection of infection in dairy settings) led by Indian Institute of Technology (IIT) Delhi

and funded by ESRC/Newton. It is one of our objectives to further develop these links and create impact outside the UK. During the REF period, and funded by MRC, we ran a series of workshops with UK and Indian scientists and clinicians aimed at promoting further interactions. We will build on this work to develop new consortia in the field of anti-microbial resistance, potentially extending into viral epidemics as well.

### ***An evaluation of our current research position***

*Grant income:* Research sustainability is supported by recent successes in individual fellowships, grants, and by partnerships with industry. Details are provided in Section 3.

*Research outputs:* Following the appointments of Rimmer (2015) and Hickey (2014), the school has focused on recruiting early career staff; these staff have proved an excellent asset, producing significant numbers of outputs submitted to REF. As an example, Barry joined Bradford in 2016, and since then, has published 15 papers as corresponding author in journals such as *Angewandte Chemie* and *Chemical Communications*, from his results obtained in Bradford. The achievements already made by our newly appointed early-career academics suggest exceptional vitality, sustainability and a thriving research environment.

*Impact:* We are actively developing a multi-disciplinary and progressive approach to chemistry, in house and with external collaborators, exemplified by the recent patent between Bradford and Aston University on the development of novel metal-based antibiotics. Although in a phase of reconstruction, with most of the academic staff recruited in the second half of the REF period, we can already evidence impact in the development of a range of potential high-value compounds, such as novel sensor elements for bacterial pathogens, new anticancer drug candidates, new and sustainable materials. We are developing broad impact that reaches international and UK audiences (e.g., industrial partners, teachers and A-level students) by developing new products with industrial partners and by offering novel teaching methodologies to schools. Swift's Case study (ICS B8-1) on better utilising functional polymer chemistry in the marketplace illustrates our collaborations with local businesses within the chemical (White Sea and Baltic), medical device (Trio Healthcare) and cosmetics (John Drury) sectors (see Section 4 for wider contributions with industry). The case study (ICS B8-2) put forward by Barry, Martin, Pitto-Barry and Comerford-Boyes (the latter from the University's Psychology Division) on the Molecular Music project exemplifies how the UoA can offer novel teaching methodologies to A-level students which facilitate learning and engagement with Chemistry for future generations.

### **Open science**

Our open science strategy is to make use of both social media platforms and far-reaching local actors (e.g., Bradford National Science and Media Museum, Bradford Science Festival, Bradford Community Broadcasting (BCB) radio). Chemistry staff are very aware of the crucial role the University plays within the Bradford area community (see details in the institutional environment statement) and proactively engage with local schools (illustrated by our ICS on Molecular Music), and the general public. Please see Section 4 "engagement with the community".

The School actively makes the scientific outputs of its staff accessible to all levels of an inquiring society: for example, the full text of our publications is deposited in Bradford Scholars, the University of Bradford open access repository. Our quarterly School Newsletter also contributes to the open dissemination of our research outputs *via* short lay descriptions of published articles. This Newsletter is accessible to anyone through the University website (<https://www.bradford.ac.uk/chemistry-and-biosciences/newsletter/past-newsletters/>) and directly sent to the School's staff, students and alumni.

### **Research integrity**

The University is a signatory to the Universities UK (UUK)'s concordat to support research integrity and to the San Francisco Declaration on Research Assessment (DORA) - see institutional environment statement. Our Chemistry research is underpinned by adherence to the

University's ethical framework and ethical code and upholding the Committee on Standards in Public Life's principles of Selflessness, Integrity, Objectivity, Accountability, Openness, Honesty, and Leadership. Ethical practice in authorship is monitored by our School Executive, which advises on best practice and is responsible for dispute resolution. New staff are also inducted into the University's ethics policy which commits to maintaining high ethical standards in research. Ethical compliance and research involving human participants, tissues or databases of personal information requires advance approval by the Research Ethics Committee. All projects involving the use of animals (in collaboration with the ICT) have passed University scrutiny through the ethics process.

## 2. People

Chemistry has grown significantly since 2014; one professor in 2015; four lecturers and one Reader were appointed in 2014, six lecturers were appointed in 2016, four in 2018, one in 2019 and three in 2020. Chemistry research is currently undertaken by 13 lecturers, three senior lecturers, one reader and two professors.

**Leadership:** The previous HoS of Chemistry and Biosciences (Rimmer) was appointed in 2015 (Chair in Chemistry) with the aim of rejuvenating Chemistry at Bradford, for example by recruiting a team of research-active academics, organising the refurbishment of the research facilities, securing Royal Society of Chemistry (RSC) accreditation for our teaching programmes (awarded in December 2020), and restructuring the School. Having completed his period of tenure as HoS, Rimmer's duties as Professor of Chemistry include leading a cross-Faculty research grouping promoting research work at the interface of chemistry, materials and the biosciences. We are currently recruiting a new HoS to drive forward the ambitious trajectory forged in this REF period.

**Academic Staff:** Since 2015, a strong emphasis has been placed on recruiting, developing, and retaining exceptional early career research (ECR) staff, who we consider essential to achieving sustained excellence in research in the long term and who have joined Bradford in their first permanent academic position. High-calibre ECRs display ambition and drive coupled with fresh ideas and creativity, and boldness to try out new directions, giving the School agility and responsiveness. We have been successful in attracting some of the best early career academics from around the world to create a dynamic and forward-looking research environment with staff hungry for success. This strategy proved to be very successful, as exemplified by our grant successes (Section 3).

Following the strategic formation of the two research clusters in 2015, synthetic chemistry was identified as suffering from clear gaps and required attention. The appointment of SR began to fill this gap and new appointments have continued to expand the core set of capabilities and skills. For example, in inorganic synthesis led by Barry (recruited in 2016) and Pitto-Barry (recruited in 2019) there is considerable synergy with the exceptionally strong organic synthetic activities led by Crawford and Hamed (recruited in 2020 and in 2018). The Polymer and Biomaterials Chemistry Group led by Rimmer is juxtapositioned alongside leading work in Polymer Engineering. Computational chemistry can offer much needed answers to fundamental questions. To meet this need, an important recruiting effort has been focused on this area, with the appointment of four lecturers between 2014 and 2018 (Seaton, Pike, Hughes, Stewart).

**Career development support for researchers:** The Unit provides strong career development support for its researchers. ECRs benefit from being part of a significant cohort of other early-career staff within the Faculty. Support and training for career development are provided through mentoring by a senior colleague within the faculty, whilst working through a personal development plan designed to develop competencies and skills. Skills and competences for all staff are developed via workshops in best practices (e.g., grant writing) and training courses delivered by Research and Innovation services (RaIS).

*Training:* All School members (established and new) fulfil statutory learning requirements and ensure compliance with key legislative areas by engaging with courses and e-learning modules developed by the University for all staff in the following areas: health and safety; diversity in the workplace and unconscious bias; data protection, freedom of information and information security. Line managers and staff involved in staff recruitment also complete modules on recruitment and selection. A range of optional e-courses focused on leadership capabilities and personal development are also available with new resources developed in response to the current pandemic. Across the School, 69% of staff attended some form of non-mandatory training from 2014 to 2019.

The School supports staff after a selection process to join leadership programmes. Two academics (one female, one male) and two professional support staff (one female, one male) enrolled in and completed the Bradford:Leader programme, and have been promoted. Bradford:Leader is a leadership training course offered by UoB for academics and professional support staff. Three female academics joined the Aurora programme (see Institutional Statement) in 2020, and three more will join in 2021.

*Appraisal/development review:* Performance and development review (PDR) takes place annually using the University's approved procedures. All new staff (including postdoctoral researchers) are assigned a mentor as part of the induction process. The mentoring process is set out in the institutional guidelines, "The Bradford Academic" (see Institutional Statement).

*Support given to academic staff for career progression:* We provide a highly supportive environment where success is valued and we offer fast-tracked career progression for our outstanding ECRs (e.g. Barry was recruited as Lecturer in 2016, promoted to Senior Lecturer in 2018, and to Professor in 2020). Promotions follow strict guidelines within "The Bradford Academic".

*Research opportunity:* To ensure and maintain vitality, the School is committed to creating opportunities for staff. Thus, ECRs have a restricted teaching load for the first two years to enable them to develop and establish their research. However, staff at all career stages are expected to teach and research. Chemistry staff have been successful in applying to the University Research Development Fund Research and Innovation Pump Priming Grant Scheme (e.g., GBP80,000 each for Barry and Hickey/Swift for PhD studentships, GBP12,000 for Barry to carry out preclinical evaluation of organometallics with the ICT).

The School facilitates sabbaticals as a way of infusing vitality into an individual's research. Examples of opportunities include three months spent in Ghent by Swift (funded by RSC) and an invited professorship (2017) in University of Lyon by Nayak. Opportunity is also created by means of an incentive fund, which is allocated by the School to all staff to enable them to present results at conferences, develop collaborations, and/or purchase consumables or software. This support is particularly useful to ECRs as they attempt to secure grants and other colleagues seeking pump-priming support.

The Faculty and School seminar programmes expose staff to exciting research being carried out by leading researchers (both internal to Bradford and external) and provide opportunities to build collaborations. The School provides opportunities for all staff, particularly ECRs, to take up positions of responsibility (e.g., in School committees) and be involved in strategic decision-making, demonstrating trust in their abilities and encouraging personal development.

**Research students:** Our PGR numbers are increasing fuelled by our growing reputation for research excellence and internationalisation. Currently (2019-20), our cohort of 19 academics in the UoA supervises 17.1 equivalent (*i.e.*, sum of all partial supervisory duties) PGRs. Our aim for the next period is to secure an average of two PGRs per FTE (an increase from the current 0.9 per FTE) by developing multi-disciplinary graduate training centres at the chemistry/biology and chemistry/materials interfaces.

Research in the Faculty of Life Sciences provides a highly supportive environment for PGRs and facilitates exchange of ideas, expertise and skills. We fully subscribe to UKRI's Statement of Expectations for Doctoral Training, the principles and precepts of the QAA Code of Practice for Postgraduate Research Programmes, and the Researcher Development Programme (RDP) endorsed by UKRI. Students are given generic and specific training to enable them to be more effective in their research, manage their careers, and be more competitive in the career marketplace. During induction, all doctoral students complete a training needs analysis exercise with their supervisory team to identify a schedule of training throughout their research programme. This forms part of the student's Personal and Professional Development Plan and maps to The Researcher Development Framework from Vitae to ensure that our doctoral training aligns with the principles set out in the concordat to support the career development of researchers. To this end, the University takes a collaborative, whole-institution approach to training and development for PGRs. All faculties and professional services come together to provide PGRs with access to a range of opportunities aimed at extending their personal transferable skills to enhance their research experience and employment prospects. In addition to generalised training in research design, ethics, writing skills and literature/data management, specialised content and training is available in a range of areas aligned to Medical Research Council skill priorities, including mathematics, statistics, bioinformatics, digital healthcare, imaging and business innovation in the life sciences. PGRs also attend and contribute to research seminar series, journal clubs and an annual Faculty Research Open Day and PGR conference as part of their training and development.

The School's PGRs have at least two supervisors providing academic guidance. In 2019, a mentoring scheme was introduced to provide pastoral and academic support independent of supervisors. To measure the effectiveness of this new scheme questions will be included in the next postgraduate survey. Students at all levels can obtain career advice and support from supervisors/mentors as well as from the UoB careers service. The 2019 survey found that PGRs thought the level of training and support was adequate and we are seeking to improve on this. In response to feedback given in the same survey, we now ensure that Knowledge Exchange (KE) activities are better advertised.

**Equality and Diversity:** Reflecting the University's strong position on equality, diversity and inclusion issues, the UoA has a strong ethos of diversity. Thirty-seven percent of the 19 Chemistry FTEs are women. Our academic staff also come from a range of countries and continents with 11 (58%) British academics, four (21%) EU nationals, and four (21%) from outside the EU. Our ethnicity data (as defined by the Office for National Statistics) is as follows: 15 White (10 White English/Welsh/Scottish/Northern Irish/British; one White Irish; one Irish Traveller; three Any other White background); three Asian/Asian British (one Pakistani, one Indian, one Chinese); one Other ethnic group (Arab).

The School of Chemistry and Biosciences holds Athena SWAN Bronze status (2018) and has a designated Equality, Diversity and Opportunities Committee (EDOC) to oversee, promote, and encourage equality and diversity in all areas of School activity, including research. The EDOC committee consists of nine women (F) and eight men (M) representing the School's diversity in sexuality and gender identities, grades, full (FT) and part-time (PT) working and caring responsibilities. The committee is formed of academics from all levels (junior three F, four M; senior three F, three M), professional support staff (two F, one M) and a research assistant (F). The EDOC lead sits within the School Executive.

The EDOC committee ensures all action points from our Bronze Athena SWAN application are implemented and leads on all Athena SWAN-related issues. The School has now begun to expand our thinking beyond gender balance to other issues such as ethnicity, a sector-wide issue in Science, Technologies, Engineering and Mathematics (STEM) also identified in our data. The EDOC meets monthly, and membership is reviewed regularly to ensure a full representation of gender and ethnicity. Time spent on the EDOC is recognised in the workload model. The EDOC communicates with staff and students at the bimonthly school staff meetings or *via* e-mail, as appropriate. One of the EDOC objectives is to promote equality within the

research environment. Several actions have been taken, for example regarding the enhanced support provided to academic female staff taking maternity leave, with contact days and available nursery places, and enhanced research support when returning to work. The EDOC also feeds into the recently launched Faculty Equality and Diversity forum.

All staff are required to undergo online diversity and equality training. Statistics are regularly reviewed to ensure that policies are being adhered to both in terms of equality/diversity as well as harassment. Self-assessment activities include:

- staff survey (May/June, yearly) with ca. 80% response rate (25 F, 31 M, one non-binary)
- postgraduate student (postgrad) survey (August) with >85% response rate (11 F, eight M)
- interviews with staff recently on maternity/paternity leave
- interviews with former School staff on leaver-related issues

Following the success of the School's policy on accessing career breaks, it has been implemented University-wide. Clearer processes regarding flexible working and other issues are currently developed with HR. Building on the Athena SWAN Bronze application analysis, we continue to track achievement of our SMART goals through annual staff/student surveys and continuous improvement of policies and procedures. The honest reflections of our staff regardless of gender, ethnicity, disability and other protected characteristics will enable progress. We particularly endeavour to ensure:

- Protected characteristics have no impact on opportunities for career progression.
- The School is open and transparent, producing excellence with procedures in place to support the diverse set of needs and circumstances of all staff.

As the School grows, we will ensure that we enhance our equality and diversity and our commitment to equal opportunities is expressed in our strategy that the department should strive for Athena SWAN Silver.

### 3. Income, infrastructure and facilities

**Income:** The development of Chemistry at Bradford is a strategic aim and this has been led by a University investment in staff and the beginnings of investment in infrastructure for synthesis (for example GBP400,000 invested in synthetic laboratories for polymer and biomaterials chemistry in 2020), alongside the long-standing support for analytical instrumentation and infrastructure. Our interdisciplinary research focus at the interface between Chemistry, Biology, and Materials broadens our funding opportunities and allows us to target most major funding research councils and foundations in the UK as well as European sources and including UK overseas aid (GCRF). In the international setting the MC grouping enjoys substantial collaborative and funded (Wellcome Trust, MRC/DBT, ESRC/Newton) projects with colleagues in India (LV Prasad Eye institute, IIT Delhi, IIT Kharagpur) around the area of materials for combating anti-microbial resistance. Recent examples of our industry-focused work include project CAYMAN (see Section 4).

Our research portfolio, over the REF period, totalled £1,823 million. The major part of our income was derived from research councils and Royal Society (40%), UK-based charities (13%), UK central bodies (22%) and from industrial partnerships, and UK Industry (18%). The rest was derived from a mixture of tax credits, EU, non-UK industry and charities.

This track record gives us confidence that we have the potential to secure the level of grant income required to underpin our research ambition. The aspirational research funding portfolio (based on our track record and plans) in broad terms is about 40% EPSRC, 10% BBSRC, 20% other (NERC, British Heart Foundation, Wellcome Trust), 15% EU, and 15% Industry. The target



for grant income is at least GBP150,000 per FTE on average per year compared to an average of approximately £96,000 per FTE per year during the current REF cycle.

**Strategy to increase funding income in 2021-2027:** All academic staff are encouraged to submit grant applications every year. The quality of the research outputs published by our academic staff gives us confidence that our research is sustainable, robust, exciting and vibrant. We have put in place a number of strategies in order to encourage the production of high-quality grant applications, as follows.

There is University-wide training to all academic staff in grant writing, resource planning and costing, research ethics and meeting the requirements of specific funding calls. The workload model includes time allocation for grant writing.

Writing retreats are offered twice-yearly to academic staff who need to have focused time in order to complete their applications. These retreats are attended by senior staff members and Research Development Managers to help complete the financial details, rework of some specific aspects of the proposals. They are designed to leave enough time for each academic (or group of academics) to work on their proposals (usually, half a day) and also to offer talks and advice on specific grants or themes (the other half day). Catering and accommodation are offered *in situ* to enable more informal discussions in the evenings. During the 2020 pandemic, online retreats took place. The Faculty also has a Business Development team (1.3 FTEs) which is highly effective in linking individual academics to industrial partners. As a result, Chemistry recently received a GBP24,000 ICURe grant SETsquared and Innovate UK to conduct a market validation study. Industrial partners include EQ Limited and 5D Ltd. The School aims to increase engagement with industry across all aspects of our work and in 2020 has inaugurated an industrial strategy board that will advise on both research opportunities and training/teaching in the context of the UK Industrial strategy.

At a School level, biannual research away-days are organised to promote informal discussions between academics, to plan collaborative research, or to plan future grant applications. An excellent example of the value of the research away days is the January 2020 event, which featured the use of the School's computational expertise in both Chemistry and the Biosciences and which has initiated new projects in photoinitiation and the use of bioinformatics to assess biodegradation of polymers in the environment. Additional bespoke seminars from researchers who recently had awarded and/or rejected grant applications with a view to sharing learning among all staff are also organised. With strategies combining incentive, encouragement, support, feedback, and dedicated time, as well as our outstanding research outputs, we are sure that our strategy will lead to an increase in funding income in 2021-2027. We have already seen early successes with a recent Leverhulme Award (Barry, GBP111,549, awarded June 2020) and, since the end of the current REF period, an Academy of Medical Sciences Springboard Award to Yorke (the fourth consecutive AMS Springboard Award for the School over the last 4 years).

**Use of major national and international facilities:** Our top-flight research is supported by the use of major facilities such as Diamond Light Source. Barry was Principal Investigator of the project SP11314 "Microfocus XAS studies of novel osmium nanocrystals on TEM grids", which took place at beamline I18 in April 2015 for two days (six shifts). This work resulted in a Chemical Communications publication. Stewart secured beamtime for SANS in 2020 (120 hours) and SAXS (72 hours) work on polymers and other materials within the Central European Research Infrastructure consortium (Grätz and Budapest).

**Infrastructure and facilities:** Facilities for chemical analysis are a strong feature of research at Bradford and the significant facilities of the AC, led by Telford, cover all the modern techniques applicable to MC and CBS research, including capabilities for proteomics, metabolomics and polymer mass spectrometry. The AC provides a centralised analytical facility for all researchers and is the hub of analytical science for Chemistry. Telford has led the development of significant and impactful networks since its inception, continuing to maximise coverage in the period since

2014. One of the key enablers in this context is the multi-disciplinary approach that the Centre fosters, providing support for all the researchers linked to the chemistry group in some form and the ongoing and significant work undertaken with industry through Knowledge Exchange (KE) activities (see Section 4). The AC provides all the usual NMR, mass spectrometry, chromatography, adsorption and vibration spectroscopy, particle characterisation, and imaging instrumentation of a modern chemistry department. The AC has strengths in mass spectrometry and NMR and features state-of-the-art high-resolution mass spectrometry (Orbitrap) for accurate mass and proteomics and 600 MHz NMR for solution based 1D, 2D and 3D experiments as well as the highest field dedicated diffusion probe in the UK. The University provides the Chemistry staff with unlimited access to the extensive analytical facilities within the AC. The University invested in updating the 400 MHz NMR with a new console (GBP220,000) in 2017 and, in 2020, upgraded the 600 MHz NMR via a successful matched bid to EU infrastructure funding (ERDF, CAYMAN project, see Section 4). Matched funding from the University has established the Polymer and Biomaterials Chemistry Laboratories, which sit alongside the Polymer IRC and features modern facilities for polymer analysis and synthesis. The University has also invested in new techniques such as fluorescence spectroscopy, Raman spectroscopy, and new thermal analysis equipment.

The computational needs of the team are provided by a newly installed high-performance computing facility comprising 2200 CPU cores, which is supported at University level. Computational expertise now resides within both of the research clusters and includes expertise in quantum mechanical methods, molecular dynamics and coarse grain methodologies.

Materials Chemistry research benefits from close working within the Polymer IRC, who enjoy extensive facilities for polymer processing and characterisation (e.g., GBP3,419,000 funding received from EPSRC EP/L027011/1; 01/2014 to 01/2024). A significant benefit of the combined School structure (School of Chemistry and Biosciences) is that Chemistry staff also benefit from biological facilities and both Rimmer and Barry run cell culture facilities whilst Rimmer, Katsikogianni and Swift enjoy access to microbiology facilities. Hamed has also established a large-scale protein and small molecule fermentation and purification/chromatography facility within the school.

Facilities for synthesis are presently adequate to carry out world-leading research but will require updating and renewal in the coming years. We aim to establish new synthetic laboratories in the medium term and in 2020 we have invested in new, improved air handling capacity. Part of this renewal has started with the new synthetic facilities mentioned above.

Support for impact generation is enabled by our facilities in the AC, with examples detailed in Section 4, "Examples of research collaborations".

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

*Industry collaborations:* West Yorkshire has a longstanding history as one of UK chemicals sector hubs. This originates in the first Industrial Revolution with the need to supply dyes to the textile industry. Although some of the former mills, and their accompanying industries, are now world-famous tourist sites (e.g., Saltaire World Heritage Site), the chemical industry is still vibrant in the Bradford area with a large concentration of chemical manufacturers (for example paper and water chemicals businesses Solenis and Kemira based in Bradford, Lubrizol located in Huddersfield, Solvay in Halifax, and Nufarm in Bradford). The School of Chemistry and Biosciences has an industrial board, which helps to guide the direction of the School research in aspects that can be relevant to commerce. This helps to keep a good balance between blue skies fundamental research and translation of chemical technologies.

KE projects enabled by the AC facilities have delivered over GBP2,000,000 in commercial value (Telford) since the Centre's inception to more than 100 companies ranging from spinouts and start-ups to international scientific leaders across all chemical sectors including AstraZeneca, Novartis, Syngenta, BASF, Solenis, Nufarm, Dr Reddys, Leon Pharma, Envigo, Dechra, Ashland, RB, Unilever, Ra Pharma, Verona, Smith & Nephew and Systagenix. Many of the KE

studies have contributed to highly impactful projects, including analytical and formulation work for Curapel™ in development of their eczema treatment creams and multiple projects undertaken recently with a biotechnology drug discovery company to support paediatric clinical trials of a potent antiviral compound in the late stages of development for the treatment of respiratory syncytial virus (an infection which claims up to 160,000 global deaths per year).

Telford capitalised on this long-term demonstratable KE success and was awarded a European Regional Development Fund (ERDF) project in conjunction with Rimmer under the 'Promoting Research and Innovation (Priority Axis 1b)' programme supported by European Structural and Investment Funds totalling GBP1,600,000 in 2019 (GBP796,147 funding awarded for 07/2019 to 09/2022). The project, entitled Chemistry Assets for Yorkshire Manufacturing (CAYMAN), covers a three-year programme of work to establish the UK's highest field NMR with a dedicated diffusion probe (Bruker DiffBB installed on 600 MHz superconducting magnet) and engage with Leeds City Region small-to-medium-sized enterprises (SME) under discrete research and innovation projects to help them improve their new and existing processes and products using UoB infrastructure and expertise. The true impact of this project will be measured at mid- and end-of-term by an independent consultant through our summative assessment, though after a year and despite Covid-19, we are overperforming on contracted outputs (for example specific ongoing SME interactions, new to company processes, new to market processes) both in number and quality compared to initial predictions made at the bid stage.

Newly recruited academic staff are all aware of this exceptional concentration of potential partners with whom to work and deliver impact, and part of the strategy for chemical research is modelled on the highly successful Singapore A\* Institute in Chemical Science and Engineering, which is also geographically positioned within a very large Asian hub of the chemicals industry. Several partnership agreements have already been signed between academics and companies (e.g. 5D Ltd) for the further development of technologies developed in the School. Five patents have been granted for our academic staff since 2015 (three for Barry/Pitto-Barry, two Rimmer/Swift).

Since 2019, Telford has been an official member of the scientific team on the European Space Agency's (ESA) Search for Life Signatures 'ExoMars' project in conjunction with Emeritus Professor Howell Edwards to provide interpretation of Raman spectroscopic data obtained by the Mars Rover when it lands on the planet (launch delayed from 2020). Prior to the interpretative side of the project, Telford has been involved in experimentation in collaboration with the University of Leicester to establish Raman Spectroscopy as part of the suite of analytical equipment that has been miniaturised for inclusion on the Rover. The project is eagerly followed by national and international press and scientific commentators alike. It has a total cost approaching EUR1,000,000,000 from the member states of the ESA and Roscosmos, which include Canada and Russia as well as European states.

Work in collaboration with groups at University College London have led to several high-impact publications in the area of 3D-printed pharmaceuticals, with Telford underpinning these outputs with bespoke analytical approaches to studying the formulations. This is a developing area and is picked up routinely in the national press. In 2015, the group published a paper examining the engineering of novel oral dosage forms to tailor drug release characteristics (subsequently cited 234 times).

Rimmer and Swift work extensively with colleagues in India aiming to find solutions to the global issues of antimicrobial resistance and polymer science. The general aim of these programmes is to develop novel polymers for cost-effective, mass-produced diagnostic devices to inform improved stewardship of antibiotics and involves collaborations with L.V. Prasad, Hyderabad (Development of a rapid system for diagnosing corneal infections using pathogen-responsive polymers (0998800/B/12/Z) and UK-India Centre for Advanced Technology-Minimising Anti-Microbial Resistance (MR/N501888/2)) and IIT Delhi/University of Edinburgh and other partners (DOSAH-Diagnostics for One Health and User Driven Solutions for AMR"(ES/S000208/1)). The

work on infections in eyes has progressed to successful *in vivo* safety and efficacy pre-clinical animal trials.

Hamed won a three-year industrial partnership award (BBSRC) with Lucite International and Ingenza Limited (GBP430,000). Hamed is also actively collaborating with universities in the Middle East (e.g., Assiut and Minia Universities, Egypt) and Europe (e.g., with Dr Jasmin Mecinovic, University of Southern Denmark). Hamed's group is currently hosting three PhD students and two PDRAs working as assistant lecturers to Egyptian Universities (on study leave).

*Collaboration on publications:* We have an extensive range of national and international collaborators. Institutions represented include Université de Neuchâtel (Switzerland), Universities of Strasbourg and Lyon (France), Yancheng Teachers University (China), the IIT Karagpur and LV Prasad in India; the Universities of Bath, Birmingham, Bristol, Warwick and UCL (UK), Diamond Light Source (UK), Advanced Light Source (Berkeley, US), CNRS Grenoble (France).

**Examples of interdisciplinary research and collaborations:** Interdisciplinary research is a central part of our vision (see Section 1), so support for it is embedded in our strategy. Examples include Crawford, who joined UoB in 2020 and is a core group member and work group leader of an e-COST Action (Mechanochemistry for Sustainable Industry). It has resulted in a paper published in 2020, and to the setup of several collaborations in Europe. Martin has publications with archaeology and psychology; nine staff have publications with microbiology, toxicology, cancer, immunology and skin specific biomedical researchers. Telford and Swift have collaborations with polymer engineering and an industrial focus on analytical science and materials chemistry coming from analytical centre. A significant number of our outputs are interdisciplinary, with applications in the domains of energy, sustainability & environment, life sciences and health care, and materials. The submitted impact case study 'Molecular Music' (ICS B8-2) resulted from interdisciplinary research between chemistry and psychology. Together with Lucite and Ingenza, Hamed is currently engineering a bacterial strain for bioproduction of a commodity chemical from renewable resources.

**Examples of leadership in academic community and esteem:**

*Learned societies:* All our Chemistry staff are either members of the RSC or the ACS, with six CChem, and three FRSC.

*Invited/plenary lectures:* Rimmer is a regular contributor to scientific meetings and since 2014 has given 10 invited and keynote lectures at international meetings. The success of our strategy to support the growth of Chemistry at Bradford *via* mainly new early stage appointments is indicated by several invited lectures: (i) Barry, Invited Lecture at the 9th International Symposium on Bioorganometallic Chemistry (ISBOMC'19); Invited Lecture at the TopNotch Meeting in Cambridge in 2019; Keynote Lecture at the UK/Russia Biomaterials workshop in Lancaster in October 2019; (ii) Stewart, invited international lecture at The Indian Polymer Group International meeting (Dec 2018, Pune); (iii) Pitto-Barry delivered an invited seminar at Institut Galien, Paris in 2019; (iv) Crawford delivered the plenary lecture at the "New Year Symposium" at RWTH Aachen University, Germany; (v) Nayak delivered an invited talk at Researcher Links Workshop (organised by British Council) on Hydrogen Storage, 2015, in Pretoria, South Africa. In the summer (June-Aug) of 2017, Nayak was appointed as an invited professor in University of Lyon where he delivered an invited seminar.

*Journal editorship/editorial boards:* Hamed on the editorial board of Scientific Reports.

*Grant review panels:* Rimmer reviews for the EPSRC as well as international funders (SFI-Eire and Finnish Academy); Nayak for RSC Research Fund and EU HORIZON-2020, and Stewart for the Royal Society; Pitto-Barry for NERC and the ANR (Agence Nationale pour la Recherche - France).

*Organisation of conferences:* RSC Biomaterials Annual Meeting 2018 (Barry, Javid), RAPS 2018 (Kastikogianni, Javid) and RAMS 2020 (Nayak).

*Awards:* Hamed won the Assiut University Encouragement Award in 2016 (Egypt) and Seal of Excellence Award from the European Commission in 2017.

*Fellowships:* Barry holds a Royal Society University Research Fellowship and Pike won a UKRI Future Leaders Fellowship while in Bradford.