Institution:
Sheffield Hallam University

Unit of Assessment:
UOA05 - Biological Sciences

1. Unit context and structure, research and impact strategy

Context and Structure

Research in UoA5 at Sheffield Hallam University (SHU) has addressed the University's Transforming Lives strategy by confronting major medical and societal challenges in partnership with business, the healthcare sector and academia. The 36 research-active academic staff (33.5 FTE) within the Biomolecular Sciences Research Centre (BMRC) focus on challenge-led applied and interdisciplinary research. During the REF period, we have realised plans to increase our academic staff base, grow research income and develop new areas in collaboration with external partners. Since 2019, **Clench** has been Head of Research in the BMRC; before 2019, the Head was **Woodroofe**.

Our research portfolio and network of regional, national and international interdisciplinary collaborations has been developed over more than 20 years. Our unique portfolio of expertise in mass spectrometry imaging, analytical microbiology and laboratory models to reduce and replace animals in research has enabled collaborations with partners including industry (Croda, AstraZeneca, Bayer, Labskin [UK]), defence (DSTL), law enforcement agencies (West Yorkshire Police) and healthcare providers (Sheffield Teaching Hospitals NHS Foundation Trust).

The BMRC, which is the research arm of the Department of Biosciences and Chemistry, is positioned within the Industry and Innovation Research Institute, alongside our major interdisciplinary collaborators the Materials and Engineering Research Institute (UoA12).

In 2019, SHU and its partners established two strategic research centres in Sheffield to which the BMRC is the major contributor of biomolecular expertise: the Advanced Wellbeing Research Centre (AWRC; partnered with Canon Medical Systems, Westfield Health and parkrun) and the National Centre for Excellence in Food Engineering (NCEFE; with >50 food-industry partners including major national and international brands). **The missions of AWRC and NCEFE are closely aligned with our aim to perform impactful research to promote health and benefit industry.** The theme lead for *Living with Chronic Diseases* in AWRC is **Dalton** (Reader in UoA5), who has facilitated our communication and collaboration with AWRC.

Research Themes and Pathways to Impact

The BMRC conducts its research through three themes, centrally coordinated and closely aligned to our expertise.

> **Theme 1: Development and application of tissue models to alleviate disease and infection** (18 academic staff)**.**
>
> **Theme 2: Application of advanced physical analytical methodology** (11 academic staff).
>
> **Theme 3: Antimicrobial resistance and biofilms** (7 academic staff).

Each theme is supported by senior staff (reader and above) who head specialist research groups that provide a focus for staff to maintain and develop key expertise, as well as providing suitable fora for support of PhD students and postdoctoral research associates (PDRAs). Our Knowledge Transfer and Consultancy team operate across all themes. Each theme has impact in its mission and is associated with a current driving societal challenge. All have led to substantial impact; one Impact Case Study (ICS) has arisen from each.

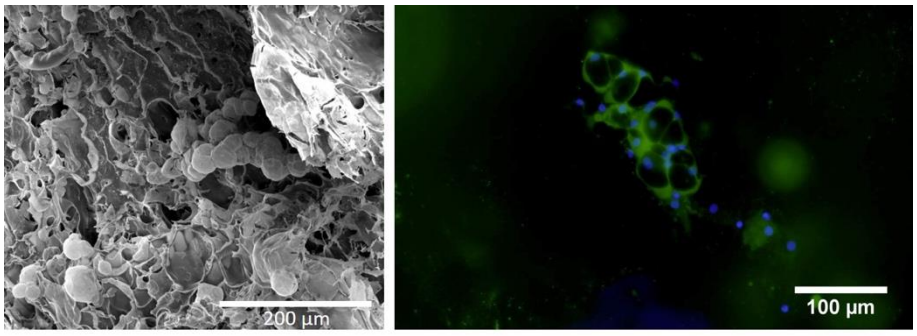
Theme 1: Development and application of tissue models to alleviate disease and infection.

Driving Challenge: **Reduction in development time for pharmaceuticals and medical devices**

This theme has brought together our expertise in mass spectrometry imaging and three-dimensional cell culture to develop *in vitro* and *ex vivo* systems modelling diverse human tissues. This has addressed a major societal need to accelerate development of pharmaceuticals and medical devices and to improve the success rate of Phase 1 trials. Work led by **Clench** in partnership with Labskin Ltd. (with funding from Innovate UK; KTP010322) has led to the Living Skin Equivalent product, a full-thickness 3D-cell cultured skin model for preclinical testing of pharmaceuticals and other products. A suite of three-dimensional cancer model systems based on alginate beads devised by **Cross N** has been developed with funding from NC3Rs (NC/L001896/1) in partnership with BioIVT, to produce the PhaseZero® 3D Oncology OrganDot™. **These two tissue model systems – representing healthy skin and solid tumours – became commercially available to the wider academic and commercial communities**, as detailed in our ICS2 *Improved methods for replacing animals in pre-clinical studies*.

In collaboration with AstraZeneca, **Clench**, **Cross N**, **Smith D** and **Cole** demonstrated multimodal MS mapping of tumour models (Analytical Chemistry 10.1021/acs.analchem.0c02389). Cancer immunologist **Leyland** (previously anticancer immunotherapy developer at Medimmune; Clin Cancer Res 10.1158/1078-0432.CCR-16-2000), with **Cross N** and **Bricklebank**, is expanding our portfolio of 3D cancer models with an internally funded studentship to study of the role of the PD-1/PD-L1 axis in solid tumour development, toward improvement of anticancer immunotherapy.

Le Maitre has pioneered development of 3D culture systems that include physiologically relevant physical load and hypoxia, that are omitted from other models. They include *ex vivo* and *in vitro* models of the intervertebral disk and disk degeneration and the intestine during inflammatory bowel disease (with **Jordan-Mahy**; Acta Biomaterialia 10.1016/j.actbio.2017.08.035). University investment (£150,000) in equipment to monitor tissues (models and *ex vivo* samples) under diverse forms of physical loading aims to develop an international centre of excellence in this area. **Le Maitre** and **Aberdein** collaborate on loading and physiology of the spine toward improved tissue models and impact through new therapies for spinal disorders. **Le Maitre** and **Cross A** have shown the roles of cytokines and chemokines during intervertebral disk degeneration and associated changes in blood vessels and nerves (e.g. Osteoarthritis and Cartilage 10.1016/j.joca.2015.02.017).



SEM and fluorescence microscopy of regenerative cells cultured within a novel biomaterial framework (iPSPINE project)

A biocompatible and physically robust hydrogel system, where gelation is thermally triggered, has been developed by Le Maitre in collaboration with Sammon (polymer scientist, UoA12). **This is ideal for regeneration of degenerated intervertebral disks and other load-bearing tissues** (Acta Biomaterialia 10.1016/j.actbio.2017.03.010). It has been validated *in vivo* (Oncotarget 10.18632/oncotarget.24813) and in post-mortem human spinal tissue under load, with funding from the MRC Biomedical Catalyst (MR/P026796/1). Research funded through Horizon

2020 (825925; iPSpine) and Innovative Training Network (Disc4All; 955735) is further developing it for regenerative therapies for disk degeneration.

Campbell and **Allen** have shown the role of eIF2B mutations in perturbing the integrated stress response in the fatal childhood neurodegenerative disease Leukoencephalopathy with Vanishing White Matter (VWM) (J Biol Chem 10.1074/jbc.RA120.014956). With funding from Great Ormond Street Hospital Children's Charity, they are characterising the precise molecular role of eIF2B mutations in VWM disease and screening potential therapeutics *in vitro*.

Cell biologist **Haywood-Small**, with analytical scientists **Cole** and **Clench**, is funded by the June Hancock Mesothelioma Trust (PhD studentship) to apply mass spectrometry, breathomics, flow cytometry and histopathology to investigate mineral fibres and biomarkers for improved early diagnosis of mesothelioma.

Dalton, working with Reynolds (honorary Professor, formerly at Queen's University Belfast), has studied the genetic causes of predisposition to obesity in patients receiving antipsychotic medication (Int J Neuropsychopharmacol 10.1017/S1461145713001375), toward development of personalised medicine to tailor antipsychotic prescribing to polygenetic risks of obesity. Bioinformatician **Crooks** uses computational methods to identify rare mutations associated with human diseases (including schizophrenia; Nature Neuroscience 10.1038/nn.4267). Several staff use molecular, cell biology and immunohistochemical methods to study human diseases: **Kelly** (pathologies associated with abnormal testosterone levels; Endocrine 10.1007/s12020-016-1019-1), **Klymenko** (role of nuclear lamina in neurodegeneration and cancer; Leukaemia 10.1038/leu.2017.255), **Laird** (recurrent miscarriage), **Principalle** (temporal lobe epilepsy; Eur J Neurosci 10.1111/ejn.13652), **Woodroofe** (multiple sclerosis, with funding from the UK MS Society; Multiple Sclerosis J 10.1177/1352458513519354).

Smith D has applied ion mobility mass spectrometry and biophysical techniques to decipher protein aggregation in neurodegenerative diseases (Biochem J 10.1042/BJ20150159). **Peake** investigates the mechanism of inflammatory bowel disease and bowel cancer, and explores the role of extracellular vesicles in health and disease. Work funded by Bowel Research UK determined the role of transglutaminase-2 in determining the solidity and prognosis of bowel cancers (Cancers 10.3390/cancers11050701).

Within Theme 1, leadership is provided by specialist group heads **Le Maitre** (Professor; Tissue Regeneration and Biomechanics), **Cross N** (Reader; Cancer) and **Dalton** (Reader, Health and Disease, also theme lead at AWRC).

Theme 2: Application of advanced physical analytical methodology.

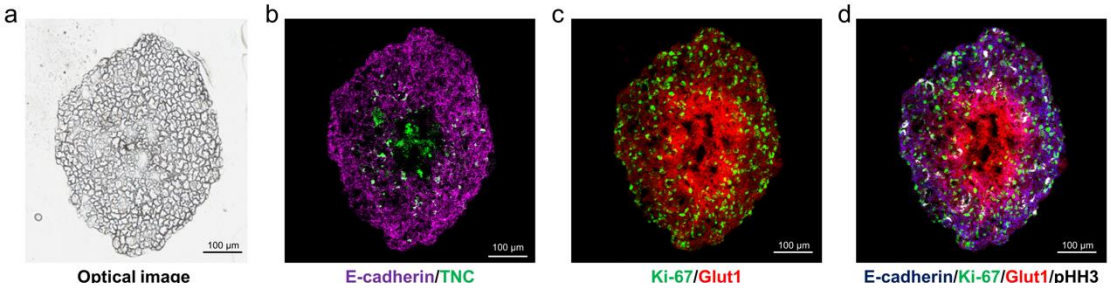
Driving challenge: **The crisis in Forensic Science: harnessing the emerging capabilities in technology**

Clench pioneered use of MALDI mass spectrometry imaging for spatially and temporally resolved analysis of drug metabolism (e.g. in brain tissue; Analytical Chemistry 10.1021/acs.analchem.5b02998). **Francese,** in collaboration with **Bradshaw** and **Cole,** has pioneered application of mass spectrometry imaging and other analytical techniques to gain information on activities and lifestyle from the minute traces of metabolites, macromolecules and contaminants present in fingermarks (Scientific Reports 10.1038/srep11716). **Through work with law enforcers, this has brought a paradigm shift to forensic fingerprint analysis** and has addressed the crisis of available technology for forensic science, a significant part of which was that no major advance in fingerprint analysis had occurred for a century. See: ICS1 *Criminal Profiling through molecular fingerprinting*.

Bricklebank and **Gardiner** use sensitive inorganic analysis to address commercial and environmental problems. **Bradshaw** is developing high-sensitivity analytical techniques for monitoring contaminants in food, through a PhD project in collaboration with NCEFE. **Schwartz-**

Narbonne uses mass spectrometry to profile organic material from environmental and biotechnologically relevant organisms in the present (Global Biogeochemical Cycles 10.1029/2019gb006282) and the remote past (Scientific Reports 10.1038/srep09791).

Herigstad researches the physiological effects of low-level environmental carbon monoxide exposure (J Cerebral Blood Flow Metab 10.1177/0271678X19887358). She presented to the Medical Working Group of the All-Parliamentary Carbon Monoxide Group in 2019; her research was instrumental to the resulting recommendations to NICE for the reduction of guideline indoor safe levels of CO. **Hamilton** (computational chemist) collaborates with Whiteoak on development of catalysts for C-H bond functionalisation and CO_2 capture using first-row transition metal catalysts to avoid reliance on palladium and other precious metals (Chem Eur J 10.1002/chem.201705785). **Turega** researches molecular recognition at the interface of biology and chemistry (J Am Chem Soc 10.1021/ja504269m). His work with **Principalle** and **Dalton** yielded a novel strategy to select monoamine oxidase inhibitors based on complementary substrate and enzyme engineering (Org Biomol Chem 10.1039/c9ob01558b). **Allwood** researches novel reactions for C-C bond formation (e.g. Organic Letters 10.1021/ol5011714) and is developing photocatalytic routes to antimicrobials aimed at new bacterial targets, through an internal studentship with **Miller** and **Hamilton**.



Mass spectrometry imaging of a 3D tumour model

The **Centre for Mass Spectrometry Imaging** (led by **Clench**), a centre of excellence for applications of mass spectrometry to biological problems established in 2018, resides within this theme, and also contributes to Theme 1**.** Within Theme 2, leadership is provided by specialist group heads **Francese** (Professor; Analytical Sciences) and **Bricklebank** (Professor; Chemistry).

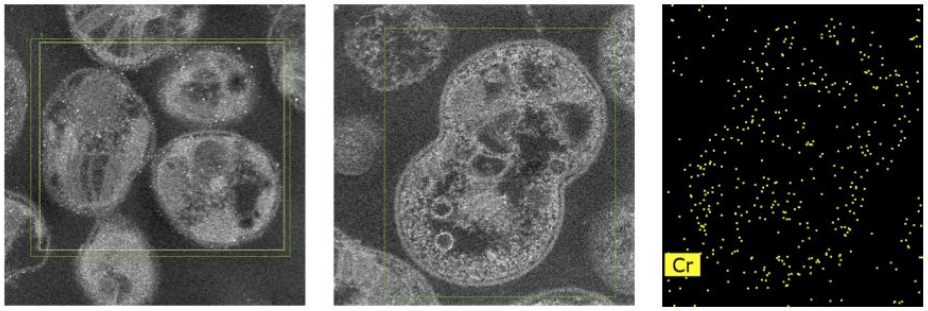
Theme 3: Antimicrobial resistance and biofilms.

Driving challenge: **Microbiological solutions to clinical and environmental emergencies**

Our research to combat antimicrobial resistance spans optimised use of existing antibiotics (**Smith T**, **Nichol**), developing new antimicrobials from natural and chemical sources (**Allwood**, **Miller, Forbes, Smith T**), better understanding of the interrelationship of biocide and antibiotic resistance (**Forbes, Lacey, Smith T**; Antimicrob Ag Chemother 10.1128/AAC.01892-18) and gene control networks in microorganisms (**Omara**; PLOS Genetics 10.1371/journal.pgen.1007253). **Stafford** investigates the role of anaerobic oral pathogens in activation of platelets causing cardiovascular disease, and (with **Campbell**) their role in inducing intracellular stress.

Our work on physical strength and antibiotic elution characteristics of cement materials has informed surgical practice on use of antibiotics, in the context of increasing antibiotic resistance, by enabling scientifically informed use of antibiotics in orthopaedic materials. This work forms the basis of our ICS3 *Antimicrobial materials: better outcomes for orthopaedic surgery*. Work that commenced in the last REF period to develop tuneable hybrid sol-gel systems for release of antibiotics has continued with MRC-CiC funding toward a wider range of applications.

Our work on environmental microbiology, aimed at bioremediation and controlling harmful trace gases, centres on the expertise of **Smith T** and **Nichol** in the molecular microbiology of methylotrophic bacteria, combined with **Gardiner**'s analytical skills (Appl Environ Microbiol 10.1128/AEM.01379-19). **Smith T** and **Nichol** collaborate with materials scientists at Manchester University (R. Akid [emeritus since 2019] and B. Connolly) on technology, including immobilised environmental microorganisms, to deter biocorrosion and biofouling (Bioelectrochemistry 10.1016/j.bioelechem.2019.04.005).



TEM and EDX showing accumulation of Cr within methanotrophic bacteria during bioremediation of Cr(VI)

Within Theme 3, leadership is provided by specialist group head **Smith T** (Professor; Microbiology).

Research and Impact Strategy

Our strategy aims to increase understanding of biological processes and systems in an interdisciplinary context, to transform lives through better healthcare, smarter applications of analytical methods and better care of the environment.

Review of progress since 2014

Our REF2014 strategy sought to build on our previous successes with interdisciplinary research, through four main research aims and our impact strategy. This includes development of our support for Early Career Researcher (ECRs), gender equality and support for impact generation that received positive Subpanel feedback from our REF2014 submission.

1. ***Capacity building:*** *Two staff will be recruited p.a. targeting researchers with a track record which complements and builds upon current strengths.*

We have exceeded this, with 17 new research-active staff (nine female; eight male; all ECRs on appointment) and have focused research work into the three research Themes (above), aligned with our expertise.

2. ***Income generation:*** *We aimed to: increase our research income to £1.2M p.a. by targeting research councils and medical charities; foster existing collaborations and nurture new, strategic partners; consolidate internal peer review of external bids and seek input from our departmental Pharmaceutical Industry Advisory Group.*

We have increased income in a challenging funding environment (total income, including grants, studentships, commercial and QR income, increased from £603,000 in 2015-16 to £936,000 in 2019-20). We have had major bid successes with funders, including MRC Biomedical Catalyst, NC3Rs, European Commission and Great Ormond Street Hospital Charity, totalling £2.1M.

We have established new collaborative networks, including the MULTIFORESEE forensic imaging COST action (CA16101) led by **Francese**. Other major funding successes have been accompanied by new partnerships, for example two EU funding networks in tissue regeneration (**Le Maitre**). We have built industrial partnerships to commercialise 3D living tissue models and

obtain joint PhD funding (e.g. BBSRC-CASE with CRODA obtained by **Clench**). Senior staff now provide feedback on all grant applications. We have strengthened links with our Pharmaceutical Industry Advisory Group, e.g. industrial representation on internal studentship panels. Members of the Group advised on return to laboratory work during the COVID-19 pandemic. Since 2013-14, commercial income has increased from £28,000 to £150,000 p.a.

3. ***PhD student recruitment:*** *We planned to: support two internally funded PhD studentships p.a., with priority to new staff; target CASE and charity-funded studentships, and cofounding from industrial partners; maintain recruitment of overseas government funded students (2-3 p.a.).*

Internally funded PhD studentships have exceeded the target every year since 2013-14. PhD student enrolment has increased from 35 FT and 6 PT students on 1/10/2013 to 42 FT and 1 PT on 1/10/2019. There have been 66 doctoral completions, compared with 32 in REF2014. We have obtained excellent results for research student satisfaction in PRES, being ranked 1st in the UK in biological sciences in the 2019/20 survey.

4. ***Multidisciplinary research engagement:*** *We aimed to promote multidisciplinary research through internal and external collaborations, specifically around our strength in biomaterials*.

Multidisciplinary collaborations remain central to our research. All our ICSs are multidisciplinary. EU and MRC funding for development of spinal regenerative medicine (totalling £1.7M) is in collaboration between **Le Maitre** and Sammon (UoA12). Nine other staff have active collaborations with UoA12. Interdisciplinary working between UoA5 and UoA24 (sport) includes work by **Dalton** on physical activity and antipsychotic-related obesity and by **Woodroofe** on exercise and recovery after cancer surgery (Breast Cancer Res 10.1186/bcr3643).

Impact strategy: *We planned to capitalise on staff expertise, seek funding from TSB (now Innovate UK) and to work toward impact with a renewed portfolio of stakeholder partnerships.*

We have focused our activities under three key themes that fit with our expertise, obtained funding to promote impact from public and private sectors (including Innovate UK) to yield impact in 3D tissue models, fingermark analysis and antimicrobial materials, through three case studies in collaboration with commercial, law enforcement and healthcare stakeholders. We have brought impact planning to the fore in strategic planning of all our work, most notably biomaterials and analytical science. **Francese**, who was successful in generating impact for fingermark analysis in the law enforcement and wider public arena, was appointed as departmental impact lead, keeping impact high on our agenda.

Research and impact strategy until 2027

1. **Capitalise on University investment and infrastructure to increase the BMRC's external standing and research income.**

We will further the University's Transforming Lives strategy via applied impact-driven and challenge-led research, toward securing the BMRC as a leading centre of applied interdisciplinary biomolecular research.

The University and partners have invested substantially in development of the strategic centres AWRC (£14M) and NCEFE (£10.3M). We will work with AWRC and NCEFE, their external networks of industry and research partners, and the University's Research Institutes, to develop new partnerships to access research funding. The BMRC will contribute to shaping these opportunities (**Clench** and **Smith T** serve on the leadership groups of the Industry & Innovation and Health Research Institutes, respectively; **Dalton** is a theme lead at AWRC). For example, we will use networks and connections at AWRC to expand on a project already funded by Yorkshire Cancer Research to investigate the underlying mechanisms of the success of physical activity prehabilitation before cancer surgery, toward more nuanced implementation of prehabilitation, balancing the benefits with the disadvantages of delaying surgery.

We will further collaborations with the regional NHS, particularly where Sheffield has national expertise, such as genetic medicine and orthopaedic microbiology. We will expand our work with local businesses via consultancy through the Sheffield Innovation Programme and via facilities recently secured through the European Regional Development Fund (ERDF) (detailed below). We will develop overseas partnerships toward international strategic development goals.

We will exploit investment from the UK Government and ERDF, plus matched University funding, in establishing a new Testing, Imaging and Characterisation Centre (TICC) at SHU (total equipment investment £2.73M) to support regional businesses in biomaterials. We plan to double our annual research income by 2027.

2. Maintaining our research staff base

UoA5 has 64.8% staff with Significant Responsibility for Research (SRfR), which exceeds the University's target of 50% for 2027. We aim to maintain this level of research engagement and use future appointments to strengthen and diversify the research themes. We will support ECRs to develop their research portfolio through successful grant applications. We aim to increase the number of PDRAs (to eight by 2027) to further increase research outputs and impact.

3. Consolidate PhD student recruitment and engagement

We aim to recruit at least five internal and ten externally funded students per year. In the wake of the COVID-19 pandemic, we will strive to maintain student wellbeing and further improve KPIs (e.g. completions, publications and high satisfaction in PRES). We will support supervisors to gain national recognition with the UK Council of Graduate Education.

4. Expedite impact from our research

Senior research staff will foster a culture of impactful research through proactive engagement across the academic faculty and our external networks. Priority areas for future impact are: (Theme 1) More sophisticated and diverse three-dimensional tissue models; tissue engineering for disk degeneration and other diseases; (Theme 2) Increasing the resolution and throughput of mass spectrometry imaging; new applications for analytical techniques; (Theme 3) Coatings containing novel antimicrobial agents to combat antimicrobial resistance. We aim to realise clinical/commercial impact in these areas during the coming REF period.

Open Research

University provisions for open access (OA) for outputs and research data, detailed in the Institutional Environment Statement, have led to high awareness of the importance and advantages of OA publication and staff engagement with OA. Staff deposit accepted manuscripts in the University's research archive (SHURA). The University supports gold OA when required by funders. It also funds gold OA of other papers, assessed on the basis of research excellence, with priority also given to researchers returning from parental leave and ECRs, as a "career kick-start". Fourteen papers were supported for gold OA between 1/10/2016 and 31/7/2020.

Library research support staff work with academics to make research data available via the University's research data archive (SHURDA). Where IP considerations permit, we make the results of our work available via conference presentations at academic, clinical and trade conferences, ahead of journal publication. Our public engagement activities also bring our work to the attention of a wider audience.

Research Integrity

All research in UoA5 undergoes ethical scrutiny in accordance with the University's ethics policy (described in the Institutional Environment Statement). Nineteen academics with SRfR served as ethics reviewers during the REF period; training is provided at University level. **Clench** and **Jordan-Mahy** serve on the University Ethics Committee. **Clench** is joint University human tissue lead.

We foster a culture of research integrity and respect for data. All researchers show and discuss their data in research group meetings. Research students receive training in research ethics, record keeping, storage and presentation of data, as well as the use of statistics to promote reproducibility of data. Laboratory notebooks (paper or electronic) are inspected regularly. Electronic data are stored on a secure central drive backed up regularly.

2. People

Staffing Strategy and Staff Development
The BMRC has a critical mass of 36 academic staff (33.5 FTE); through a strategy of recruitment and development, it has more than doubled in size since the submission of 17 staff to REF2014.

Staffing strategy
Recruitment through increasing student numbers has enabled us to build our research staff base. We have a joined-up recruitment policy where senior staff responsible for research (led by **Clench**) and teaching (Head of Department **Laird** and deputy **Bricklebank**, both research professors) work together to appoint staff who will advance teaching, research and research impact. We have recruited seventeen new staff (nine female; eight male) with strong research backgrounds across our research Themes.

New staff:
Theme 1 – **Aberdein**, **Allen**, **Crooks**, **Kelly**, **Klymenko**, **Leyland**, **Peake**
Theme 2 – **Allwood**, **Bradshaw**, **Hamilton**, **Herigstad**, **Schwartz-Narbonne**, **Turega**
Theme 3 – **Forbes**, **Nichol**, **Omara**, **Stafford**

Our research community includes a substantial cohort of PhD students (increasing slightly from 41 to 43 during the period), five PDRAs, two graduate research assistants and 1-3 commercial research staff, plus DProf and MRes students.

Career development
We support career-long researcher development, in line with the Academic Careers Framework detailed in the Institutional Environment Statement. Our recruitment of early-career academic staff, together with a strong tradition of retaining and developing staff, ensures a balanced community. This facilitates succession of roles of responsibility when staff are promoted or retire, since our staff is uniform across the various career stages. Three staff have left to relocate to other academic posts (UK, Australia and Spain). Five staff (14%; four female, one male) are currently ECRs. All other appointees (four female, six male) were ECRs on appointment.

Early-career researchers
The research group leads within each theme mentor new staff, advising on impact, collaborations, funding applications and publication. New staff with research potential and aspirations are allocated research time, to assist in establishing their independent research careers. This allocation is made with individually agreed forward-looking objectives, aligned with the BMRC's research themes and University priorities, taking advantage of the skills and experience of the new staff. Research time allocation is reviewed annually as part of the appraisal process, according to the University REF Code of Practice. Opportunities for internal PhD studentships prioritise ECR staff.

The Departmental ECR champion links local ECRs to the wider University ECR Network, supported by University Research and Innovation Services (RIS) with a dedicated experienced lead. In 2018-19, ECR staff **Aberdein** and **Forbes** benefited from internal competitively awarded Chancellor's Fellowships (each providing research funding around £30,000). By 2019-20, these enabled **Aberdein** to obtain an internal PhD studentship and **Forbes** a research grant (£9,990) from the Healthcare Infection Society. ECR staff are supported to apply for start-up grants from diverse funding bodies and to participate in ECR networking events organised by the professional societies.

Career-long researcher development

Annual Research and Scholarly Activity review meetings with research leads are a forum for discussion of research and impact plans, target setting and progress review. Established staff can bid for additional research time against individually agreed objectives aligned with the wider research strategy. Mid-career staff are encouraged to apply for promotion to reader. Candidates for promotion to chair are mentored by experienced professors. University workshops on "How to become a professor" are open to all staff. The Aspire (internal) and Aurora (AdvanceHE) mentoring schemes provide career development support and mentoring for female staff; six female staff in UoA5 have benefited. Female and male staff have contributed as mentors in other UoAs. University funds have been available for fellowships to develop research impact, from which **Francese** benefited after promotion to chair.

All academic staff can request internal staff development funds, typically used for attendance at an international research conference. At least one such activity has been supported annually for all staff who made requests. Internal review (with feedback) from research group leads is mandatory for grant applications and available for research manuscripts.

Postdoctoral researcher development

PDRAs attend research staff meetings, which include career development aspects such as funding opportunities. They are able to access all the same central university activities as permanent staff. PDRAs can gain teaching experience and are encouraged to apply for associate membership of the Higher Education Academy to improve their employability within the HE sector. Three PDRAs have obtained permanent academic posts here and elsewhere during the REF period.

Recognition and reward

Eight staff have been promoted to senior (reader and professor) research positions. Impact is embedded in the academic and promotion criteria through the Academic Careers Framework and has contributed to these promotions. Three staff were promoted from Senior Lecturer (NFA grade 8) to Reader (NFA grade 9; **Cross N**, **Smith D** and **Dalton**), one from Senior Lecturer to Principal Lecturer (NFA grade 9; **Jordan-Mahy**) and two from Senior Lecturer to Reader and subsequently Professor (**Le Maitre** and **Francese**). **Bricklebank** and **Laird**, who were already senior staff with departmental leadership roles, were awarded personal research chairs. A further 15 members of staff progressed from Lecturer (NFA grade 7) to Senior Lecturer.

Research Students

Overview

Research Postgraduate students are an integral and valued part of our research community. PGR provisions and training are overseen in the Research Institute by the Head of Research Degrees, **Le Maitre**, who is a Recognised Research Supervisor by the UK Council for Graduate Education. The departmental Postgraduate Research Tutor (PgRT; Duckett) provides pastoral support (including focus groups and bimonthly "matters arising" sessions) to complement the support given by academic supervisors and research groups.

Our Department has obtained excellent results from successive national Postgraduate Research Experience Surveys (PRES). In 2019, **we obtained the highest overall satisfaction rating (97%) in the UK in Biological Sciences**. Nominations from our students have led to three University Inspirational Research Supervisor awards (**Le Maitre** 2016 and 2020, **Forbes** 2019). In 2019 the University award for Outstanding Student Support (Research) was won by our student support officer (Rea Smith). In 2020 the same award was won by our PgRT (Duckett).

Our research community includes students undertaking extended projects (≥6 months) on M-level programmes: MSci (accredited by the Royal Society of Biology to produce "research-ready graduates"), MChem (accredited by the Royal Society of Chemistry) and MRes.

Recruitment, induction, training and supervision

All PGR applicants are interviewed (in person or via telephone/video call) before an offer is made. Admissions criteria align with the QAA UK Quality Code for HE. Each student is supervised by a team of at least two staff with subject expertise and supervisory experience. New PGRs attend a full-day Research Institute induction event. Locally, they meet with supervisory teams and give short introductory talks to the Department. Electronic resources are available on Blackboard (VLE), which complement the cooperative and student-centred support provided by academic supervisors, the research groups and PgRT. Student- and project-specific training needs are assessed at the start of the programme when students complete the Vitae Researcher Development Framework Planner.

Training operates at three levels:

1. Research good practice, including record keeping, data management, analysis and statistics, literature retrieval, research integrity, ethics, and health and safety. This is provided through sessions delivered at University, Research Institute and Department level, including input from staff in UoA5 (e.g. scientific writing sessions by **Smith T**), e-literature experts from the Library and online training (including mandatory ethics training) using Epigeum;
2. Specific research methods and instrumentation required by individual programmes, which is provided by academic or researchers, on an individual or small-group basis;
3. Transferable skills, personal development planning, career choices, employability, time management, teamwork and leadership. These are delivered at University and Research Institute level.

We consider training of others an essential part of researcher development; hence, experienced PhD students are encouraged and expected to participate in techniques training for new students and, occasionally, PDRAs or academic staff. Our skilled Departmental technical team (three with PhDs) have experience across all our instrumentation.

As an example of where we embed the interdisciplinarity of our research practice into the training and development of future researchers, we hold an annual winter poster session jointly with UoA12 at which all PhD students present. A team of three to four academic staff judges, spanning both research areas, individually speak to every student presenter. Hence every student has meaningful scientific conversations with specialists and non-specialists. Prizes for the three best posters are awarded. PhD students can also present at the Research Institute Doctoral Showcase and the University Creating Knowledge research conference. All PGRs present their work at one or more international conference(s). Students are encouraged to take part in local and national rounds of the Vitae “Three Minute Thesis”.

The University Research Degrees Committee (RDC) monitors **PGR student progress**. The Research Programme Approval form is assessed (at 3 months for full-time students; 6 months for part-time) by an independent rapporteur. A full supportive progress review is undertaken at 10-12 months, encompassing an oral presentation and viva, a written report in the style of a journal paper and literature review. A review and thesis plan early in the final year ensure monitoring and support throughout the study cycle.

Support for supervisors

New PhD supervisors undertake the University Doctoral School’s Research Supervisor Development Programme. Supervisor development sessions (at which at least annual attendance is mandatory) provide continuing support for supervisors and are a forum for new staff to benefit from the enthusiasm of established members, and for established staff to learn from the experience of newer ones.

Research student funding

Internally funded PhD studentships are allocated competitively to staff based upon review by a panel that includes senior staff from UoA5, the Research Institute, RIS and an external member

from the Department's Pharmaceutical Industry Advisory Group. Criteria include alignment with University and UoA priorities. Prioritisation is given to teams led by ECR staff. Students from SHU and beyond can also apply for annual Vice Chancellor's scholarships, where student and supervisor work together on the application, which is assessed at University level.

Our student body is ≈25% overseas and ≈75% home/EU. Home students have been funded through: internal studentships, BBSRC CASE studentships with GSK, and Croda, DSTL, H2020 and the Marie Skłodowska-Curie Action COFUND as part of the Bioscience for Health Doctoral Training Alliance of modern universities. Staff have also obtained joint funding from outside agencies to complement internal funding: e.g. DTSL (**Francese**), Croda (**Clench**), Health and Safety Executive, Pioneer Healthcare (**Le Maitre**), Bowel Cancer UK (**Peake**), June Hancock Mesothelioma Trust (**Haywood-Small**) and Sheffield Children's Hospital (**Allen**). We have recruited overseas government-funded students from Egypt, Thailand, Libya, Philippines, Iraq and Saudi Arabia, and part-time students from industry (AstraZeneca).

Outcomes and outputs from PhD study

High standards of research degrees are maintained by appointment of appropriate expert external examiners from research-intensive departments throughout the UK University sector and Europe. All students are actively encouraged to prepare their work for publication. 36 of the 84 outputs submitted herewith have PhD student co-authors.

In 2014, 2016, and 2018 we organised one-day careers conferences, which included PhD student alumni and external keynote speakers talking about their careers, within and beyond academia. It is our mission to nurture new generations of researchers, as well as graduates who will use doctoral study as a gateway to different paths of high-level employment and endeavour.

Among the 66 doctoral students completing during the period, a substantial number obtained academic posts (five in the UK and at least eight overseas), others entered industry (four, including Novartis, AstraZeneca), the civil service (including the Health and Safety Executive), and the National Health Service (four, including a consultant clinical scientist and two into the Scientist Training Programme). Eight PhD graduates continued in research as postdocs (including SHU, University of Sheffield, Leeds, Surrey and Harvard). Patrick Harrison, who obtained his PhD with **Miller** and Strong (2014), was appointed to a permanent lectureship at the University of Hull in 2018. **Cole**, who studied for her PhD and worked as a PDRA with **Clench** was appointed to the academic staff in 2018. Similarly, **Nichol** was a PhD student and PDRA with **Smith T**, becoming academic staff in 2016. **Bradshaw** was appointed to a permanent academic post in 2018 after PhD and PDRA with **Francese**. Other PhD graduates obtained academic positions in Leicester De Montfort and Middlesex Universities.

Equality and Diversity

The recruitment, training, retention and career development of our staff are a priority, within an environment that respects the diversity of all. The Department of Biosciences and Chemistry holds SHU's only silver Athena SWAN award, which was renewed in 2019. There are currently only 18 UK departments in the biology area with silver or gold Athena SWAN awards. Our submission was commended for the high percentage of women in senior roles (four out of seven professors; two out of four readers/principal lecturers) and the high percentage of part-time staff (20% across academic staff as a whole; 17% [six out of 36, five female, one male] of staff with Significant Responsibility for Research [SRfR]), the high proportion (100%) of staff returning from maternity leave and the high uptake of paternal leave. The proportion of staff with SRfR who are female (58%) is comparable to the proportion of women on the full departmental academic staff (62%). We are implementing a three-year action plan for further improvement towards increased "beacon activities" (such as the University's implementing the mixed-gender appointment panel policy that was instigated in our Department) with the ambition of obtaining a gold award during the next REF period.

Support for staff with protected characteristics

Three out of 36 academic staff (one female; two male) have a BAME background. This (8.3%) is less than the proportion of Sheffield residents (16% BAME) and UK HE academic staff as a whole (17% BAME). Working toward increased BAME representation among our staff is part of our Athena SWAN action plan. This includes measures, now enacted, to explicitly state in job adverts that applicants from BAME backgrounds and other underrepresented groups are encouraged to apply, HR screening of adverts to ensure inclusive language, and encouraging staff to use social media to increase the diversity of applicants. Increasing equality for BAME people at all levels in the Department is coordinated by the departmental BAME lead, appointed in 2020 to focus on these issues.

We strive to be inclusive of all staff and students, across all protected characteristics. As described in the Institutional Environment Statement, SHU has thriving disability, LGBT+ and gender support networks for staff and students. Students with disabilities can seek a learning contract, built on a research-specific template, to obtain the most appropriate support and environment for work and study. A diverse range of social events are organised to celebrate festivals from different cultures and to accommodate differing attitudes to alcohol in different religions and cultures among staff and students.

Part-time/fixed term staff

We are committed to flexible working patterns to fit around the lives of our staff. We have six part-time research active staff; two were promoted to senior posts during the current period (**Dalton** [0.5FTE] from Senior Lecturer to Reader and **Francese** [0.8FTE] from Reader to Professor). **Woodroofe** worked for 18 months at 0.2FTE in transition from full-time to retirement. Three of the new academic staff appointments were initially fixed-term; all were made permanent before the end of the period. We strive to support the career development of fixed-term research staff as part of our commitment to the Concordat to Support the Career Development of Researchers. By supporting PDRAs with transferrable and teaching skills as well as research, we hope to ease their transition into permanent posts and note success in this with our former PDRAs detailed above.

3. Income, infrastructure and facilities

Research Funding

Annual research income has increased from £603,000 in 2015-16 to £936,000 in 2019-20. We have a mixed income economy including RCUK, other governmental sources, medical charities and industry. Except for smaller contract research projects, all our research aims toward academic outputs and impact beyond academia.

Collaborative networks including academics, clinicians, law enforcement agencies and industry have been central to our research an impact strategy. These have been built through local networking, conference attendance and meetings organised by the BBSRC NIBBs and University seed-corn funding such the Creating Knowledge Implementation Plan (CKIP; detailed in the Institutional Environment Statement). They have improved funding successes and given our work relevance to stakeholders, as detailed by the examples below. Most of our projects are multi-centre collaborative ventures.

Major notable projects are (funding amounts are income to SHU):

Theme 1 – Development and application of tissue models to alleviate disease and infection

Le Maitre - H2020 £1.2M (825925) with 20 academic and commercial partners in Europe, to develop advanced therapeutic biomaterials for lower back pain.
Le Maitre - Disc4All Marie Skłodowska-Curie Innovative Training Network £265,000 (955735) integrated computational simulations in translational medicine, applied to intervertebral disc degeneration.

Le Maitre MRC Biomedical Catalyst: Regenerative Medicine £202,000 (MR/P026796/1) – with Sammon (UoA12), to validate novel hydrogel systems for spinal tissue regeneration.
Campbell Great Ormond Street Hospital Charity £189,000 – molecular pathology of and developing treatments for VWM disease.
Clench - NC3Rs £242,000 (NC/L001896/1) – development of human tissue models for cancer and skin disease.

Theme 2 – Application of advanced physical analytical methodology

Francese - Joint PhD studentship funding from DSTL (together with internal Vice Chancellor's scholarship fund) to develop MS fingermark analysis – income to SHU £84,652.
Bricklebank - BBSRC CASE studentship (£99,034) with Croda Europe Ltd. (BB/S507179/1) - *Development of LA-ICPMS and associated techniques for analysis of crop enhancement products.*
Herigstad - Gas Safety Trust (£51,540) - *Impact of low-level CO on the human brain*.
Clench has worked as academic lead for the research commercialisation, most recently via the Centre for Mass Spectrometry Imaging. This has provided contract research income, increasing from £28,000 p.a. in 2014 to £150,000 p.a. in 2020.

Theme 3 - Antimicrobial resistance and biofilms

Nichol - MRC (CiC, funding held with University of Sheffield and Sheffield Teaching Hospitals NHS Foundation Trust), £60,964, development of antibiotic-free sol-gel antimicrobial coatings for urinary catheters.
Forbes - Healthcare Infection Society, £9,990, transcriptomic analysis of biocide adaptation in uropathogenic *Escherichia coli* CFT073.
Smith T - BBSRC, £15,000 (BIV-13-smith-C1net) - *Characterisation of methanotrophic bacteria to reduce ground water risks of recycling alkaline solid waste* – NIBB business interaction voucher with Ballast Phoenix Ltd. and Freeland Scientific Ltd.

Infrastructure

Organisational infrastructure
Since the mid-2000s the University has strongly supported interdisciplinarity. Co-location of the UoA5 laboratories and the Materials and Engineering Research Institute (MERI; UoA12) facilitated collaborative work, which greatly expanded thanks to pump-priming funding initiatives, including a Bridging the Gap EPSRC grant (2009-12), which initiated much of the materials-focussed antimicrobials work that underpins the ICS in Theme 3. This and later institutional cross-disciplinary funds enabled collaborations between **Le Maitre** and colleagues in UoA12 that are the foundation of the productive biomaterials work and funding income of Theme 1. University interdisciplinary initiatives have also enabled the work of **Dalton** and **Woodroofe** with UoA24. CKIP funding, which targeted interdisciplinary work, has further benefited our research to take our work into new contexts and geographies. The new University research structure (summarised in the Institutional Environment Statement) has positioned UoA5 alongside UoA12 in the Industry and Innovation Research Institute. Our connection with the Health Research Institute, NCEFE and AWRC offer further opportunities for collaboration (**Dalton** is lead for the "Living with Chronic Disease" theme at AWRC).

The SHU Library provides high quality academic resources in primarily electronic format, enabling all researchers to access a wide range of journals and other materials. Staff and students can obtain articles in journals to which the University does not subscribe through the centrally funded Document Supply Service.

A laboratory manager is responsible, together with the head of research, for health and safety in the laboratories.

Scholarly infrastructure

We have a weekly seminar programme and monthly research meetings where all staff (academics and PDRAs), as well as students, can meet to exchange news and ideas. These were particularly valuable in connecting our community when they continued on-line during the COVID-19 lockdown. They are also a forum for discussing up-coming funding calls, facilitated by "horizon scanning" from one of the grants officers from RIS. Staff are involved in the wider academic community of Sheffield, including departmental seminars and conferences at the University of Sheffield.

Supporting funding applications

Staff are encouraged and guided in funding applications via a triage and feedback process. This is essential for researcher development, and for the University's and UoA's aim to grow research funding. Staff are supported by research group leads early in the conceptualisation and writing processes. RIS support the submission and approvals process, costings and compliance with funder rules.

Research Facilities

Substantial research facilities and equipment support each of the research themes. The interdisciplinary nature of our work means that projects often use equipment from more than one theme.

Theme 1: We have laboratories for cell culture work: tissue preparation, primary and secondary culture including facilities for 2D and 3D cell culture and analysis, microscopy, plus analysis of cells at the nucleic acid and protein levels.

Equipment includes:

- Sysmex XP-300 Automated Haematology Analyser (for analysis of cellular composition of blood samples)
- Coy Hypoxic Glove Box (for hypoxic cell culture mimicking the microenvironment of many tissues in vivo)
- Invitrogen Countess Automated Cell Counter
- BD FACSCALIBUR and Gallios 10 Channel flow cytometers (for enumeration, typing and sorting of eukaryotic and prokaryotic cells)
- Olympus IX81 Motorized Inverted System Microscope
- Olympus BX60 Microscope (fluorescence, bright field and phase contrast microscopy)
- Zeiss Laser Scanning Confocal Microscope (LSM800)
- Biorad D-Code Universal Mutation Detection System
- Qiagen Pyrosequencer
- ÄKTA protein purification systems
- Nanion Port-a-Patch patch clamp system

Funding of £150,000 in 2019 from the University's CKIP "Capacity Building Fund" provided a world-class biomechanical tissue loading suite enabling testing of varied loading regimes in controlled environments:

- Electroforce 5210 (×4 BioDynamic Chambers)
- Electroforce 3D Culture Pro
- MICROTEST Microtensile loading system

Bioinformatics for genomic analysis is performed using two multi-core Linux servers, one with 256 GB RAM and the other with 512 GB RAM.

Theme 2: The Centre for Mass Spectrometry Imaging (CMSI) is a world-class facility, with high-definition imaging capabilities.

The instrumentation comprises:

- Waters Synapt G2 HDMS (with matrix-assisted laser desorption ionisation [MALDI] and liquid extraction surface analysis [LESA] sources)
- Waters Xevo G2-XS (with desorption electrospray ionisation [DESI] source)
- Bruker Autoflex MALDI/MS/MS ×2
- Applied Biosystems MALDI QStar instruments ×2
- Perkin Elmer Nexion ICP-MS with UP-213 laser ablation [LA] system (New Wave Research).
- Sample preparation using Labcyte Portrait acoustic spotter, SunCollect spotter/sprayers and Bruker "ImagePrep" matrix deposition devices.

Other analytical and MS equipment includes:

- Agilent 6420 TSQ LC/MS/MS ×2
- Agilent Ultivo TSQ LC/MS/MS
- Agilent 5800 ICP-OES
- Agilent 5977 GC-MS ×2
- Bruker 400 MHz NMR

The dedicated synthetic chemistry laboratory includes Isolera One Flash and CombiFlash rapid purification systems. Computational chemistry is performed using Linux servers including a 32-core 192 GB RAM, with computational chemistry software (ORCA, Multiwfn, Avogadro, Gabedit) and the University main High Performance Computing system with molecular dynamics simulation packages.

Theme 3: The containment level 2 microbiology laboratory has facilities for growing diverse prokaryotes and fungi. There is a gas-controlled incubator (Don Whitley MACS VA-500) cabinet for handling oxygen-sensitive organisms. Two five-litre bioreactors (Eppendorf Bioflo) are used for a range of microorganisms and, thanks to gas lines and associated safety equipment, constitute a world-class facility for large scale growth of bacteria on methane and propene. A Thermo French Cell press, together with the protein separation systems detailed above, allow large-scale purification of bacterial proteins.

Staff also have access to equipment for analysis of materials through collaborations with UoA12, to a range of equipment from other external collaborators, and national facilities such as the Diamond Light Source Synchrotron and (during the coming REF period) the TICC imaging instrumentation detailed above.

Technical infrastructure

A team of technical staff with expertise spanning the range of chemical and biological techniques manage and maintain the research and teaching laboratories and equipment base, ensuring their smooth operation. 0.5 FTE staff provide dedicated administrative support to research staff and students.

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

Collaborations, Networks and Partnerships

Since the 1990s, we have developed extensive collaborative networks within the Sheffield region, nationally and internationally. Productive and friendly collaborative working, at institutional and personal levels, among Sheffield Hallam University, the University of Sheffield and Sheffield Teaching Hospitals NHS Foundation Trust is a major regional strength that benefits all partners and creates a critical research mass in the applied biological sciences. Senior NHS consultants with current and previous honorary chairs at SHU have been key enablers of our research, including: Ian Stockley, Andrew Hamer, Robert Kerry and Mark Wilkinson (Orthopaedic Surgeons), Robert Townsend (Clinical Microbiologist), Lee Breakwell, Neil Chiverton and Andrew Cole (Spinal Surgeons), Prasad Godbole (Urological Surgeon), T.C. Li (Reproductive Medicine & Surgery) and Keith Chapple (Colorectal Surgeon).

The following are a selection of our most important collaborations:

Theme 1 (Development and application of tissue models to alleviate disease and infection)

Since 2013 our collaborations in cell biology have entered, literally, a new dimension by moving from conventional 2D cultures to bespoke 3D culture models to mimic human tissues and organs, and progressively replace animals in research. Clench and Cross N devised laboratory models of human tissues, under NC3Rs and Innovate UK funding, enabling two companies (**Labskin [UK] Ltd** and **BioVT**) to develop commercial products and services in nonanimal technologies (see ICS2 *Improved methods for replacing animals in pre-clinical studies*). Clench, Bricklebank and Duckett, with the **HealthCare Division of CRODA Ltd.**, used MS imaging to monitor drug delivery into a 3D skin model (Analytical Chemistry 10.1021/acs.analchem.8b02648), supported by University-**CRODA** funded and BBSRC-CASE studentships.

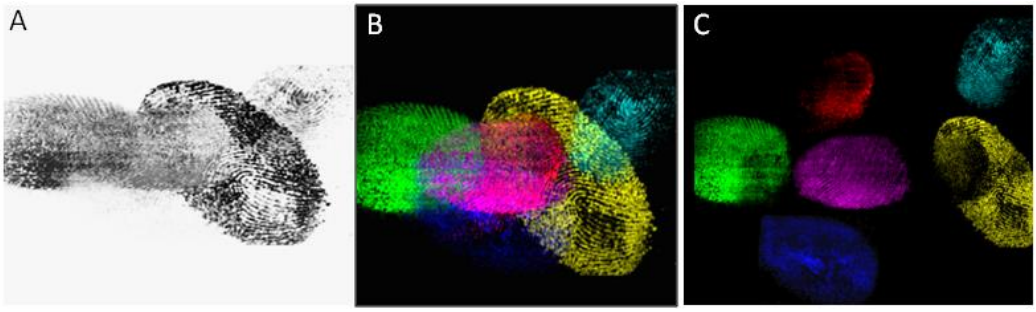
Work in Biomechanics and Tissue Engineering (championed by Le Maitre) is highly collaborative as it encompasses in vivo and clinical trials of reconstructive therapies. Collaborators include Mak Risbud (**Thomas Jefferson University, Philadelphia**) on cellular pathogenesis of disk degeneration (J Biol Chem 10.1074/jbc.M117.790378), Lisbet Haugland (**McGill University, Montreal**) and Theo Smit (**Amsterdam Medical Centre**) on loaded disc culture systems and injection of hydrogels into human IVDs, the **iPSPINE consortium** of 20 European partners, the **DISC4All EU ITN consortium** investigating computer modelling to identify pathogenesis of disc degeneration resulted, and Keith Meek and James Bell (**Cardiff University**) for hierarchical analysis imaging of IVD using synchrotron radiation at Diamond Light Source. Cross N collaborates with Jon Golding (**Open University**) developing nanoparticle-mediated sensitisation of radiotherapy (funded via a Doctoral Training Alliance PhD studentship).

Dalton and honorary professor Reynolds are leading members of the ***Genetics of Antipsychotic-Induced Weight Gain Consortium***, which includes Rotherham, Doncaster and South Humber NHS Foundation Trust and national academic partners (including **University of Manchester** and **Queen's University Belfast**).

Collaborations with John Livingston (**University of Leeds**) and Truus Abbink (**VU University, Netherlands**) are central to Campbell and Allen's work funded by Great Ormond Street Children's Hospital Charity on VWM disease. Allen and Campbell collaborate with Santosh Mordekar (Consultant Paediatric Neurologist, **Sheffield Children's Hospital**) on a SHU-funded PhD project investigating ISR in childhood neurological disorders. Klymenko collaborates with Andrejs Braun (**CRUK Bart's Centre, London**) on roles of nuclear lamina in cancer.

Theme 2 (Application of advanced physical analytical methodology)

Francese's mass spectrometric forensic fingermark analysis has been realised via a world-wide network of collaborators in law enforcement agencies. These include Neil Denison (Director of **Yorkshire and Humber Regional Scientific Support**; supported by a home-office funded PDRA; output in Analyst 10.1039/c7an00218a), Steve Bleay (ex **Home Office, CAST** now **London South Bank University**) and Vaughn Sears (retired **Home Office, CAST**). Other collaborators in the UK, Netherlands and USA are detailed in the ICS1 *Criminal profiling through molecular fingerprinting*. Francese coordinates **EU COST Action** CA16101 "MULTIFORESEE" in Forensic Science.



Overlapping fingermarks (A) distinguished via mass spectrometry imaging (B), allowing the ridge patterns to be visualised separately (C).

Clench coordinates the academic and industrial collaborative network of the Centre for Mass Spectrometry Imaging. Collaborative work with David Skiblinski and William Griffiths (**Swansea University**), **Advion Ltd**. (Harlow), Irina Pikuleva (**Case Western Reserve University, Cleveland, Ohio**) achieved spatial resolution of brain cholesterol metabolism (PNAS 10.1073/pnas.1917421117).

Hamilton collaborates with synthetic chemist Whiteoak (now in **Alcalá, Spain**; outputs include Chem Sci 10.1039/c9sc05076k). Hamilton also collaborates with Cleaver and Spencer (**UoA12**) to model liquid crystal behaviour in materials (via a University VC PhD scholarship). Turega collaborates with Peter Andrews and Steve Brown (**Centre for Stem Cell Biology, University of Sheffield**) to develop LSD1 probe molecules and peptide-LSD1 inhibitor conjugates (supported by a SHU-funded PhD studentship), and with Clegg (**UoA12**) and **Sky Chemicals Ltd.** on a co-funded PhD project to optimise peracid disinfectants.

Theme 3 (Antimicrobial resistance and biofilms)

Our network to tackle antibiotic resistance includes surgeons, clinicians and academics with specialisms that enable us to focus on precise challenges in this broad global problem (and highly competitive research area). Smith T and Nichol, supported with funds from by MRC and the Cavendish Hip Foundation, have focused on the key problems of local delivery of antibiotics (to avoid resistance problems due to prolonged systemic use). Work with NHS collaborators has enabled this research to inform clinical decisions (see ICS3 *Antimicrobial materials: better outcomes for orthopaedic surgery*).

We enjoy close collaborations with the **University of Sheffield** (e.g. Nichol's MRC Confidence in Concept (CiC) project with Paul Hatton, University of Sheffield, to develop antimicrobial-releasing urinary catheter coatings). Smith T is an external member of the **University of Sheffield's Florey Institute of Host-Pathogen Interactions**; Smith T and Forbes have spoken at Florey networking meetings. In future, we will use this network, and collaborations with Ruxandra Gref (**CNRS, Paris**; funded by Royal Society) on nanoparticles and Ehiasarian (**UoA12**) on ultrathin plasma deposited coatings (supported via CKIP funds), toward new therapeutic materials for antimicrobial protection using knowledge-based strategies to minimise resistance.

Collaboration with Mohammed Abdel Rahman (**Suez Canal University, Egypt**) provided access to North African scorpion biodiversity, from which Miller and Strong identified novel antimicrobial peptides. They performed fast atomic force microscopy mechanism of action characterisation with Steve Evans (Physics, **University of Leeds**) (Soft Matter 10.1039/c8sm00707a) and successful in vivo animal testing with collaborators in **China** (Front Microbiol 10.3389/fmicb.2018.01159).

In work on environmental microorganisms Smith T and Gardiner collaborated with Andreas Scheinhost (**ESRF, Grenoble, France** and **Helmholtz Zentrum Dresden Rossendorf, Dresden**) and Nicole Hondow (Chemical and Process Engineering, **University of Leeds**) to map inorganic species during bioremediation by methane-oxidising bacteria (Appl Environ Microbiol 10.1128/AEM.01379-19).

Knowledge transfer and consultancy

Knowledge transfer is embedded across our research themes and impact. The BMRC Knowledge Transfer and Consultancy team (one to three FT commercial research staff) is led by Clench**.** These staff deliver contract research projects and work with the central Research and Innovation team to foster commercial relationships and accelerate impact. For example, a commercial contract (£35,000) for Cancer Research (UK) used our expertise in Mass Spectrometry Imaging and Confocal Microscopy to evaluate a novel therapeutic interbladder tissue drug delivery system.

Sustainability of our networks

We continually develop our research and impact networks to have foresight of the future challenges that will drive our research in the coming years. New staff benefit from the existing networks and also bring opportunities for new connections. For example, ECR Aberdein's work on leptin in obesity-related disorders has been enabled by the collaborative network and tissue loading expertise of Theme 1 and her Chancellor's Fellowship *Role of leptin and load on trabecular and cortical bone remodelling.* At the same time, Aberdein has extended the network by collaboration on animal models of leptin-related pathologies with J.E. Hall (**University of Mississippi**; Hypertension 10.1161/HYPERTENSIONAHA.116.08560). Similarly, Forbes has taken her work on evolution of pathogens in response to antimicrobials (Nat Commun 10.1038/ncomms4742) forward through an internal Chancellor's Fellowship and two studentships, to develop a collaboration with Manikandan Kadirvel (Research Fellow; **Manchester Pharmacy School**) in microbial responses to antimicrobial stresses, to inform new smart coatings to prevent urinary tract infections being developed along with Nichol, Smith T and Sammon (**UoA12**).

Engaging Research Users

Campbell, Allwood and Nichol, with colleagues in NCEFE, provide **'Science of Brewing' KT workshops** within the Sheffield Innovation Programme (SIP), which benefits local industry. Le Maitre runs a **low back pain patient user group** to bring end-user input to her work developing novel therapies for spinal disk degeneration. Haywood-Small and Cole act as experts in annual **Action Mesothelioma Days** (Leeds; the **June Hancock Mesothelioma Trust**) to facilitate understanding among patients and families. Woodroofe was an expert at "**Meet the scientist**" sessions organised by the **MS Society** and hosted research users' visits to our facilities. Peake contributed to the "**Big Bowel Event**" patient/researcher meeting (**Bowel & Cancer Research**, London, 2019). These events bring SHU research to the attention of important stakeholders: people with the diseases we are researching, their families and the wider public.

Contributions to the Economy and Society

Herigstad contributed to the **All-Party Parliamentary Carbon Monoxide Group**. Smith D (**National Teaching Fellow and 2019 national HE Bioscience Teacher of the Year**) and Lacey coordinate public engagement activities through our Education and Outreach Group. Most staff have contributed talks to the public or schoolchildren in the annual **Sheffield Science Week**. Kelly contributed three articles on androgens to **The Conversation**, with tens of thousands of views. For example, Caster Semenya: how much testosterone is too much for a female athlete? (2019), which had >83,500 reads. A Wellcome Trust-funded project (109815/Z/15/Z) *Virtual Reality Prosthetics* (co-investigators Le Maitre and Duckett) presented research results related to biomechanics nationally in 2016-17. The group's work also promotes research-led teaching, practised by all our staff using examples of their applied research in teaching to further the Transforming Lives mission of the University.

Contributions to the Discipline

Professional society committee membership: **Clench** (*Leader* MALDI and Imaging Special Interest Group of the British Mass Spectrometry Society [BMSS]; *Board Member [International Relations]*, Mass Spectrometry Imaging Society); **Francese** (*Committee Member*, Fingerprint Society); **Gardiner** (*Admissions Committee*, Royal Society of Chemistry); **Le Maitre** (*Chairperson*

DISCs Foundation, *Executive Officer* Society of Back Pain Research, *Executive Secretary* Society for Biohydrogels [Nantes, France], *Section Officer*, Spine Section, Orthopaedic Research Society [USA]); **Miller** (*Council Member*, British Society for Antimicrobial Chemotherapy [BSAC]); **Smith D** (*Education Committee*, Biochemical Society); **Stafford** (*Secretary*, HUBS Early Career Lecturers' Group); **Woodroofe** (*International Advisory Board*, International Society for Neuroimmunology); **Omara** (*Chair*, Interdisciplinary Committee of Egyptian Academics in the UK).

Service on national funding panels: **Bricklebank** (*EPSRC Funding Prioritisation Panel*, 2017); **Clench** (*Grant Review Panel*, CRUK); **Miller** (*Grants Committee*, BSAC); **Woodroofe** (*Award Strategy Committee* and *Awards Assessment Panel*, Daphne Jackson Trust).

Organising conferences and workshops: **Clench** organised six one-day BMSS meetings at SHU on Mass Spectrometry Imaging (each attracting >100 delegates). **Francese**, scientific committee at the OurCon conference of the Mass Spectrometry Imaging Society (Saint Malo, France, 2019). **Cross N**, co-organiser, British Association for Cancer Research 3D cell culture workshop (Nottingham, 2017). **Le Maitre**, co-organiser, Spine Research Interest group, Orthopaedic Research Society Conference, San Diego; Lead organiser, Society of Back Pain Research, Sheffield (2019). **Schwartz-Narbonne** organised international workshop on Anammox Bacteria during Environmental Change (Newcastle, 2019). **Stafford** and **Kelly** hosted Northern Vascular Biology Forum at SHU in 2019.

Selected conference oral presentations: **Bradshaw**, BMSS Environmental & Food Analysis Special Interest Group (Manchester, 2019). **Bricklebank**, BBSRC Metals in Biology NIBB (Durham, 2016). **Campbell**, Translation UK (2015, 2018 and 2019); **Clench**, *Invited Talks* at meetings in the UK, Europe, China and Panama, including NC3Rs workshop on human tissue models for cancer research (London, 2017). **Francese**, prominent presentations, UK, Europe and Australia, including Biological Mass Spectrometry Discussion Group (London, 2014, awarded *"Most valued talk"*), *Invited Opening Lecture*, Royal Society of Chemistry Analytical Forum ("Cracking crime with Lasers" London, 2016), *Plenary*, Australia and New Zealand Forensic Society (2018). **Hamilton**, *Invited Oral Presentation*, Midlands Computational Chemistry Meeting (2017). **Le Maitre**, Invited presentations UK, Europe and USA, *Keynote*, SILBERSALZ Industry Conference, Germany (2018); Philadelphia Spine Research Society (USA, 2019); *Keynote*, Society of Back Pain Research (Netherlands, 2019). **Leyland**, *Invited Speaker*, Transregional B Cell Winter Immunology School, Germany (2019). **Nichol**, British Council UK-Russia Workshop on biomaterials, Lancaster (2019). **Peake**, Session Chair, UK Extracellular Vesicle Society (UKEV) Forum (2018); **Principvalle** *Invited Speaker*, "GABAB conference 2018", Italy. **Smith T**, C1-EU annual meetings; GCRF-funded collaborative meeting on environmental technology (Coimbatore, India, 2019). **Woodroofe,** MS Frontiers, Bath (2019).

Invited departmental and other seminars: **Aberdein**: Mississippi. **Campbell**: Trinity College Dublin, Manchester, Babraham Institute. **Clench**: Hull, CRUK Barts. **Smith D**: "The Dual Role of the Academic" Advance HE on-line, >400 attendees. **Smith T**: East Anglia, Queen's Belfast, Oxford Brookes. **Stafford**: Buffalo (USA).

Journal editor and editorial board positions: Androgens (**Kelly**); Biomaterials Science (**Le Maitre**); Chemosensors (**Gardiner**); FEMS Microbiology Letters (**Nichol**); Human Reproduction (**Laird**); Neuroscience Letters (**Dalton**); JOR Spine (**Le Maitre**, advisory panel); Journal of Medical Microbiology (**Miller**); Proteomics (**Clench**); Science and Justice (**Francese**); Scientific Reports (**Clench**, **Le Maitre**, **Smith T**).

Reviewing: Staff review for funders, including: BBSRC, EPSRC, MRC, Innovate UK, Wellbeing for Women, Bowel Research UK, MS Society, AISM (Italian MS Society), Mitacs (Canada), Ministry of Science & Technology (Israel), and journals including PNAS, Nature Communications, PLOS One, Amer J Resp Crit Care Med, Seizures, Human Brain Mapping, ISME Journal, Appl Environ Microbiol.

Prizes: Whilst working at MedImmune, **Leyland** received the Global Scientific Breakthrough of the Year award (2016). **Aberdein** won the APSselect award (2018) of the American Physiological Society for distinction in scholarship for an original article (Amer J Physiol 10.1152/ajpregu.00287.2017).