Institution: University of Huddersfield

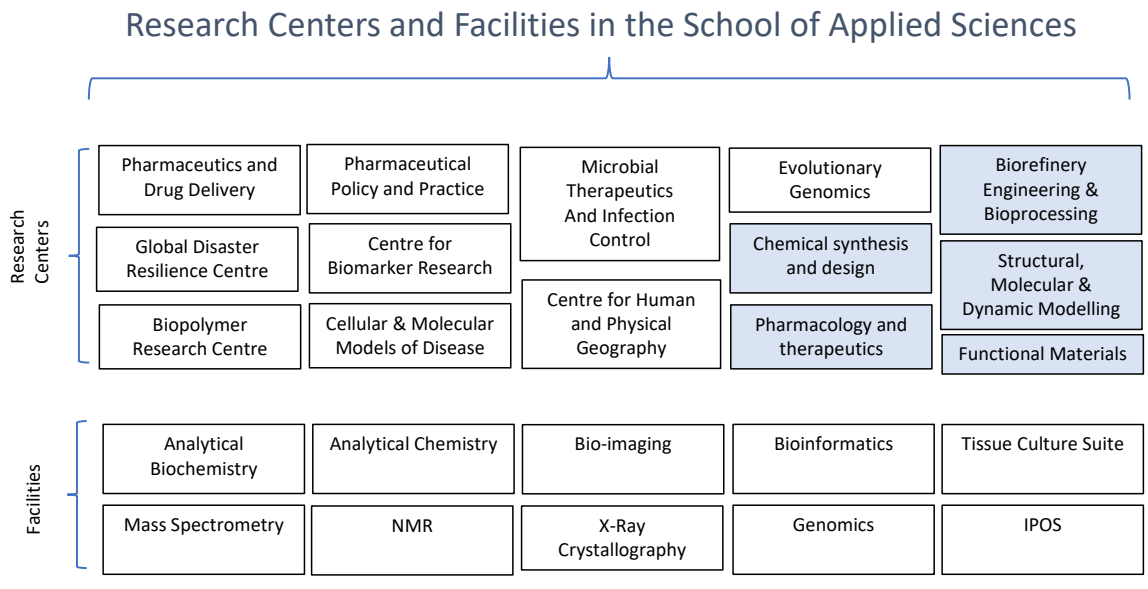
Unit of Assessment: UoA 8 Chemistry

1. Unit context and structure, research and impact strategy

The University of Huddersfield's vision is to be an inspiring, innovative University of international renown. Underneath the overarching institutional strategy, the University's Research Strategy has a primary vision of excellent research with impact contributing to important advances in human knowledge and significant improvements to the global quality of life. To achieve this, thematic Areas of Strategic Research Importance (ASRIs) have been identified including Materials and Health, the principal foci of our UoA8 submission. ASRIs embrace and promote interdisciplinary research and whilst Huddersfield's Unit of Assessment 8 is a submission led by the Department of Chemical Sciences within the School of Applied Sciences (AS), our research involves close collaboration with colleagues in other departments within AS (including Biological and Geographical Sciences, Pharmacy and Optometry).

(i) Unit context and structure:

In REF2014, our focus was on strengthening three main research groups (Synthetic and Physical Organic Chemistry, Materials and Catalysis and Supramolecular and Structural Chemistry) but due to the recruitment of new staff, initiating the Chemical Engineering programme (in 2015) and growth in research programmes, the research landscape within UoA8 significantly changed in the early part of the REF cycle. Resultantly, since REF2014, these research groups have expanded and together with new expertise within the School, they have matured leading to the creation of four defined research centres that are housed within the Department of Chemical Sciences. Other developments more widely within the School have seen an expansion in Pharmacology and Drug Discovery leading to new opportunities for interdisciplinary research. The philosophy underpinning the development of these research centres is to harness the available expertise both within AS and other Schools and to focus our activities into specific areas of expertise. Whilst we have a departmental structure within the School, these Research Centres are not organised along departmental lines but cross the various disciplines. This serves many purposes including the breaking down of barriers that can exist in a departmental structure and promotes communication between scientists with different skill sets. Staff are primary members of one research centre but can be affiliate members of other centres thereby further promoting interdisciplinary research across the spectrum of activity within the School. An overview of the research centres within AS and those that drive research in UoA8 (highlighted in blue) are presented below:



Chemical Synthesis and Design: The focus of this centre is to develop new synthetic routes and chemistries to generate novel chemicals with applications in both industry and academia. As examples, the activities of the centre include medicinal chemistry, where the aim is to develop novel compounds for drug development, and heterocyclic chemistry which supports many of the advances in modern functional materials. Topics under active study include:

- Translational catalysis
- Asymmetric synthesis
- Heterocyclic chemistry
- Medicinal chemistry
- Mechanistic organic chemistry
- Carbohydrate and natural product chemistry
- Analytical chemistry

Structural, Molecular and Dynamic Modelling: The activities of this centre focus on supramolecular and structural chemistry with a specific interest in the formation of transition metal complexes and/or the structural characterisation of these metal containing species. In addition, dynamic modelling of molecules and their interaction with the environment, biological and other molecules is a new development in this centre. The centres activities include:

- X-ray diffraction
- Molecular self-assembly
- Coordination chemistry
- Solid state chemistry
- Novel semi-conductor materials
- Structural characterisation
- Dynamic modelling in silico

Functional Materials Research Centre: This interdisciplinary group [linked with the Doctoral Training Centre (DTC) materials centre in the School of Computing and Engineering] has interests in various areas of materials chemistry including the study of ordered and amorphous porous solids and functionalised solids for application in catalysis and absorption, surface science, synthesis and electrical and magnetic characterisation of mixed metal oxides, the synthesis and characterisation of new transition metal complexes of relevance to light emitting devices and solar cells and the computational modelling of solid-state and molecular materials. The centre also embraces exploration of chromic phenomena and stimuli responsive molecules which have wide ranging applications in variable transmission devices. Activities within the centre include:

- Photochromic and electrochromic materials chemistry
- Dye-sensitised photovoltaics and light emitting materials
- Optical and electron transfer materials
- Electronic solid-state materials
- Computational materials modelling
- Advanced thermal methods for materials synthesis and characterisation
- Inorganic biomaterials
- Biosensors

Biorefinery Engineering and Bioprocessing Research Centre: Research in this centre falls into two main themes: bioprocess technologies (e.g. fermentation, extraction), and biorefinery integration. Here the aim is to create a dynamic, and integrated bioprocess industry that underpins global food security, health and wellbeing, sustainable chemicals and energy through novel technologies deployed within integrated biorefineries. Specific areas of interest include:

- Bioethanol production and the exploitation of co-products such as arabioxylans
- Fermentation and the synthesis of biochemicals and biofuels from sustainable raw materials

- Industrial ecology
- Cereals as a raw material for food and non-food processes

Pharmacology and Therapeutics: During this REF cycle, there has been a significant expansion in pharmacology thereby promoting interdisciplinary research within AS. Collaboration with a multitude of scientists across the Chemistry-Biology-Pharmacology-Pharmacy interface is facilitated allowing a direct line-of-sight between target identification, chemical synthesis and pharmacological evaluation. Chemistry is instrumental in this pipeline as it provides new compounds for evaluation encouraging a holistic approach to interdisciplinary work. Correspondingly, whilst **Pharmacology and Therapeutics** has also been submitted to UoAs 3 and 5 many chemists are members of this research centre. Research within this centre focuses on the development and evaluation of therapeutics designed to target cancer and neurological disorders. Both phenotypic evaluation of novel chemicals and the development of targeted therapeutics designed to target specific biochemical pathways that are altered in disease are areas of specific interest in this centre. The centres activities include:

- Tumour metabolism and associated molecular vulnerabilities of cancer cells.
- Phenotypic evaluation of novel molecules and target deconvolution.
- Drugs from Nature Targeting Inflammation
- Cannabinoids in the management of disease
- Biomarker discovery
- Identifying biomarkers and treatments for psychiatric disorders

This final section summarises the number of staff in this UoA. There are a total of 33 (31.5 FTE) academics and research staff in the Department of Chemical Sciences and all academics are appointed on teaching and research contracts. A total of 29 (28 FTE) academic and research staff will be returned to UoA8 with 27 classified as having significant responsibility for research (8 professors, 4 readers, 11 senior lecturers, 3 lecturers and 1 university teaching fellow) and 2 classified as Independent Researchers according to the University of Huddersfield's REF code of practice. This represents a significant increase in the number of academic and research staff submitted to UoA8 compared to REF2014 (14.6 FTE submitted in 2014). Underpinning the academic staff, we currently have 9 post-doctoral research assistants and 2 research fellows who don't formally meet the requirements for inclusion in REF2021 but contribute to the Departments research activity and culture.

(ii) Achievement of strategic aims for research and impact

Our strategic aims for **research** as stated in REF2014 were as follows:

A1 To grow the research programmes of our Research Groups in areas where we have the ability to deliver internationally recognised scientific excellence and socio-economic impact

A2 To guide the focus of our Research Groups to match industrial, governmental and EU priorities, thereby growing and diversifying our funding base

A3 To facilitate collaborative research, via both academic and industrial pathways (beyond and within the University)

A4 To sustain a vibrant graduate school, to provide the intellectual and cultural stimulus needed for postgraduate training

A5 To ensure our research has an impact on teaching, through lecture courses, undergraduate project work in our research labs and student involvement in seminar and visitor programmes

A6 To engage with the public locally and nationally, in schools, and through public lectures and other media activities.

The success of our research strategy is evidenced by the progress that the UoA has made since REF2014. As stated above, we are now submitting almost double the number of staff with 89% of

staff being classified as having significant responsibility for research or are independent researchers. Our research is concentrated in 5 professorially led research centres as opposed to the 3 research groups identified in REF2014 **(A1)**. This has led to the increase in both quality and number of outputs with a total of 475 in the 2014-2020 period, 43.2% of which were in the top 10% of journals by CiteScore percentile (SciVal analysis). Collaborative research internationally has grown as exemplified by the fact that 38.5% of our outputs have been published with international partners **(A1, A3)**. Specific examples of international collaboration leading to prominent outputs include the collaboration between **Patmore** and a group from Jinan University China resulting in a Nature Communication publication. Intra-Departmental collaborations are also very strong with work between **Gill**, **Rice** and **Patmore** on the work of iron-catalysed carbon-carbon bond formation leading to a Nature Chemistry publication. Within AS, collaborative research between the UoAs present within the school has also grown with many of the staff collaborating with both Pharmacy and Biology **(A1, A3)**. For example, **Elliott** and **Rice** collaborate with **Phillips** (UoA3) and **Allison** (UoA5) on inorganic compounds for chemosensitivity testing which has led to high impacting publications (e.g., Angewandte 2018). There is also a strong collaboration between **Hemming** and **Olajide** (UoA3) focused upon neurodegenerative disorders (Bio. Med. Chem 2020) and between **Morris** and **Smith** (UoA3) on bioactive peptides.

As described in more detail in section 3, our research income has grown ca. 2.4-fold from £1.507M in REF2014 to £3.602M REF2021. Our research funding base also demonstrates increased diversification of funding **(A2)** with collaborative research with industry being a prominent feature in REF2021 **(A2)**. The sustainability of our research during the next REF cycle is exemplified by a significant number of granted patents and sustained research funding that has been recently awarded or spans the current REF period cut off (see section 3).

Housed within the School is Innovative Physical Organic Solutions (IPOS) which is a GMP accredited facility which carries out analysis for local companies (Rosemont Pharmaceuticals and Thornton and Ross) as well as many other analytical commercial services. This facility has a turnover of £300K p.a. but is also heavily embedded within the research environment carrying out the School's mass spectroscopy service and elemental analysis. Their expertise is disseminated across the School allowing (**A3**) their state-of-the-art analytical methods to be applied to the research environment. Collaborations have led to some high impacting results (e.g. **Williams** Angewandte 2020). The unit is also active in the training of undergraduate students for the analytical industry, employing between 1~2 UoH placement students per annum as well as final year project students. Knowledge of contemporary analytical techniques are also disseminated amongst the research community allowing significant skills-research overlap. With regards to (**A4**), the number of research doctoral awards has increased from 26 in REF2014 to 64 in this REF cycle which represents a significant increase in postgraduate training.

Our research continues to enthuse our undergraduates and taught postgraduates though invigorating lecture courses that highlight our research activities. **Campbell** was awarded the Institute of Chemical Engineer's (IChemE's) Davidson Medal (2020) for the outstanding mentoring of young chemical engineers (**A5**) and **Belton** and **Campbell** were jointly awarded the 2017 IChemE's Hutchinson Medal for their stimulating paper in Education for Chem. Eng., 2016. Our Chemical Sciences seminar programme is openly advertised, and final-year undergraduates are actively encouraged to attend. All undergraduate students have the opportunity to undertake a final-year research project and these are invariably within a research-active group. Perhaps the most obvious exemplar is our sustained record of publications in leading journals within which our undergraduates have played a significant role and are credited with co-authorship (e.g. Booth, Chem Commun 2014; Qureshi, Angewandte 2020; Harper, Angwandte 2018; Comia and Ross Inorg. Chem. 2020) (**A5**). Several of our undergraduates have also published their research work in the UoH journal 'Fields' (https://www.fieldsjournal.org.uk/), established in 2015, to capture our students' contributions to research (**Whitehead** also serves on the editorial board of Fields). Such is the infectious nature of our enthusiasm for research that many of our first-class graduates apply to undertake research studentships with us.

Public engagement is widespread (section 4), and several staff are active on social media platforms. The school also participates in major initiatives such as European Researchers Night (2016 and 2017 **Gabbutt**/**Heron** demonstration lecture) and has run Chemistry Teachers Enhancement days (2015 **Hopwood**) (**A6**). In order to further realise our role in the local education community our recently completed laboratory block houses a dedicated and bespoke schools liaison facility/outreach laboratory used to house a series of GSCE / A-level practical sessions for schools and colleges to support their chemistry provision.

In REF2014, the stated **impact strategy** for UoA8 was to continue to encourage and promote impactful research in existing areas of research strength and to develop new research activities in fundamental science which will have a significant socio-economic impact. Throughout this REF cycle, the importance of impact has been emphasized through various impact training events organised in AS (research away-days and workshops for example) and our suite of impact case studies represent impact from both existing (**Heron**) and new (**Du**, **Campbell**) research areas. Heron's case study is built on extensive collaborative research with international industrial partners as described above whereas impact case studies from **Du** and **Campbell** represent new research in chemical engineering (established in 2015). Looking beyond REF2021, our strategy for supporting research with impact will continue along the same lines but with greater emphasis on training staff and the incorporation of impact in their research plans alongside School support to identify and promote projects with impact.

(iii) Future strategic goals for research and impact

Having achieved our objectives from REF2014, we have developed a new set of strategic goals that look beyond REF2021. The underlying theme is to drive our research forward by building upon our existing strengths and developing new collaborative relationships with academic institutions and end users both nationally and internationally. Our strategy for research and impact is as follows:

A1 Our Research Strategy will continue to grow the research programmes of our Research Groups/Centres in areas where we have the ability to deliver internationally recognised scientific excellence and socio-economic impact. This will be enabled by focusing upon multidisciplinary research covering activities within the School, within the University and with external collaborators and end users. To facilitate greater interdisciplinary research collaboration, the Institute of Molecular Medicine will be established within AS focusing on a 'bench to bedside' based strategy to drug discovery.

A2 To continue developing the infrastructure through the continued development of core facilities (which remain free at the point of use) and research laboratories in order to enhance the research environment and culture.

A3 To continue to support and develop staff alongside attracting new research active staff with the aim of enhancing our 'critical mass' of research active academics and support staff.

A4 Aligned with the University's strategy map, our aim is to improve the quality of research outputs (with 75% or more staff achieving 3*/4* publications by 2025 and an average of 15 citations per published output), increase our research and knowledge exchange income and develop strategic research collaborations with other world class academic institutions.

A5 Linked to improved quality in our research, our strategy for impact focuses on conducting high quality applied research and establishing formal links with unique businesses and end users.

(iv) Research Culture

Open Research: As an institution, the University supports the principles set out in the Concordat on Open Research Data and is committed to open research. In support of open research, the University has an open access policy and a research data management policy. The University has invested in systems to facilitate Open Research including the Elsevier PURE management information system and a University Data Repository and content management system (Box). Additional central support comes from the appointment of Open Access Manager and Research Data Management Officer whose roles are to provide information, to assist in the delivery of

mandatory central training for staff and students, to support the wider open research strategy and to assist academic staff in making data open and accessible.

As a UoA that prides itself on its values in applied and fundamental research that strives to make a difference, we seek to continually develop and nurture an open, collaborative research culture. We achieve this through encouraging open collaborative and collegiate interactions within and across research centres and through a vibrant public engagement programme. We actively pursue a policy of open access to our research where feasible and encourage staff to integrate strategies into research proposals to maximise engagement with and use of research outputs by research users and different audiences. Funds are available to ensure open-access publications where appropriate and relevant data is archived in public repositories (e.g. Cambridge Crystallographic Data Centre for single crystal data).

Research Integrity: In the development and conduct of our research, Research Integrity is of paramount concern. As an institution, we adhere to the UKRI developed Concordat on Research Integrity and ensure research is conducted according to appropriate ethical, legal and professional frameworks, obligations and standards. The institutional Code of Practice for Research, research ethics and integrity policy and reporting statements are publicly available on the University website. Within AS, research and integrity matters are co-ordinated by School Research Ethics and Integrity Committees (SREIC) which is responsible for implementing the Universities policies and procedures in relation to research governance. In addition, the School has a nominated Research Integrity Champion (**Phillips**) whose role is to promote good research practice, ensure that the principles and relevant standards are embedded in cross-University and local guidance and to ensure that advice is available to staff and students regarding the issue of research misconduct and the reporting thereof. Research Ethics and Research Integrity training of all staff and PGR students is embedded into the induction programme and assessment of research ethics is an integral part of all research and enterprise grant applications. Research misconduct is taken seriously across the Institution and all matters pertaining to research misconduct for PGR students and research staff are pursued along Institutional guidelines. Within the School, research integrity matters extend beyond UoA boundaries and cover collaborative research with colleagues in other UoA's. For example, compliance with the Human Tissue Act license (human tissue licence number 12641) is also ensured via SREIC ethics approval for projects in interdisciplinary areas such as drug discovery.

2. People

(i) Staffing strategy and staff development:
Our staffing strategy emerges from our strategic aim to build a research base that is internationally recognised for the quality of its research. With this in mind, we have focused on the continued development of areas of expertise as described in REF2014 (now reorganised into research centres as described in section 1) and expanded into new areas of research (e.g. chemical engineering). This has been achieved through the appointment of a balanced combination of experienced and early career researchers.

Of the 16 academic staff that were returned in REF2014, 10 remain (**Cooke**, **Elliott**, **Gill**, **Gillie**, **Harding, Hemming, Heron, Moran, Patmore** and **Rice**). During this REF cycle, a number of appointments and promotions have been made **Bexon** (L), **Bostock** (L), **Gabbutt** (SL), **Molinari** (SL), **Scattergood** (RF), **Wedge** (SL) and **Whitehead** (L). The Department has also been expanded with the creation of a Chemical Engineering group with the appointment of **Angelis-Dimakis** (SL) **Campbell** (Prof), **Chin** (SL), **Du** (appointed as Reader), **Liu** (SL), **Singh** (SL) and **Supuk** (SL) The appointment process is co-ordinated by Human Resources and research plays a key role in both the short listing, interview and decision-making processes. These appointments have strengthened pre-existing areas (**Whitehead** and **Scattergood** – inorganic/supramolecular; **Bexon** and **Bostock** – forensic science) and opened new avenues of research (**Molinari** – computational) as well as expanding research into Chemical Engineering (**Angelis-Dimakis, Campbell, Chin, Du, Liu, Singh** and **Supuk**).

Academic staff are supported by a strong contingent of technical support with both the NMR facility and the analytical suite staffed by full-time PhD qualified personnel. This is coupled by a technical team with an excellent knowledge base of chemical provision. The IPOS team are also fully embedded within the research programme and have an exhaustive knowledge of analytical instrumentation and method development.

Going forward beyond REF2021, our staffing strategy will continue to focus on the appointment of staff with excellent research experience in pre-established areas as well as Areas of Strategic Research Importance (ASRI) within the School. This includes the establishment of the Institute of Molecular Medicine which is the focus of the School's Health ASRI and this UoA will be an integral part of the Institute alongside colleagues in UoA5 and UoA8. Our focus is not just on appointing research excellent staff, but we also provide a supportive environment for staff who are returning from career breaks. For example, during this REF cycle we have appointed three Daphne Jackson Fellows within the School, the aim of which is to support women returning to academic life following career breaks to raise a family. Our staffing strategy will therefore continue to support this approach.

With regards to staff development, our approach is aligned closely to the Universities staff development processes and a multitude of opportunities exist for staff. For example, staff in UoA8 (academic and support staff) have undertaken management and leadership modules leading to the award of Member (2) or Fellow (3) of the Chartered Management Institute (CMI). Alongside staff in other areas of the School who have also completed or are enrolled on CMI programmes of study, this ambitious scheme is designed to provide managers and leaders with an internationally recognised qualification in management and the strategic aim of the institution is to become the world's first institution led and managed by Chartered managers. In addition, all staff are encouraged to become Fellows of the Higher Education Academy. All staff returned to REF2021 possess either a FHEA or SFHEA teaching qualification. All staff are strongly encouraged to be members of their respective scientific societies (e.g. Royal Society of Chemistry, Institute of Chemical Engineers and Forensic Science Society) Finally, all staff submitted to REF2021 have PhD qualifications and career development is strongly supported. An annual promotion exercise is undertaken following institutional guidelines and during this REF cycle, staff have been promoted to Professor (**Heron, Morris, Elliott, Patmore** and **Du**) and Reader (**Harding** and **Moran**).

The University is also a signatory to the Technicians Commitment which is a sector-wide initiative led by the Science Council, which will ensure greater visibility, recognition, career development and sustainability for technicians across all disciplines.

(ii) Support for postgraduate research students:
Our research students are an integral part of our research activities and the School has invested heavily in this area since REF2014. The School has used QR money (£4.449M over this REF cycle) to create fully funded studentships across the full spectrum of research activity, thirty of which have been awarded to staff submitted in UoA8. Funding covers fees and a bursary together with a consumables budget ranging from £2,000 to £10,000 per annum depending on the project requirements. In addition to school-based support, thirteen studentships have also been funded from the EPSRC doctoral training program designed to support the growth of interdisciplinary materials-based research across AS and the School of Computing and Engineering. As stated in section 1, the number of research doctoral degrees awarded has increased from 26 in REF2014 to 64 in this REF cycle reflecting substantial and sustained growth in PGR provision. All PGR students are interviewed by at least two academic staff, one of which has to be a senior academic and if successful, they are assigned a minimum of two supervisors. The main supervisor must (i) have a PhD and (ii) be publishing at an internationally recognised standard (co-supervisors will normally have a doctoral degree but maybe new to supervision). Senior Research Fellows are encouraged to take supervisory roles in conjunction with an experienced academic (e.g. **Heron/Aiken** and **Elliott/Scattergood**) and all supervisors undergo an initial three-part training course with refresher courses every 3-years to ensure they are up-to-date with regards to PGR

regulations/processes. These criteria ensure that students are assigned a supervisory team with the necessary research experience and expertise to train and manage PGR students.

With regards to infrastructure to support students the Director of Graduate Education (DoGE) assisted by two PGR and Finance Administrators oversees the management, training and progression of PGR students. On enrolment, students will undergo a full programme of induction activities covering health & safety, research culture, expectations of supervisors and students, PGR degree rules and regulations, progression monitoring and research ethics and integrity. A number of on-line resources and support are available via the graduate school. Research integrity is fundamentally important at all levels and students are informed of the Concordat to Support Research Integrity and the consequences of non-compliance. This, together with additional information about support for students, is available on our Brightspace VLE in a defined module called Applied Science PGR. Three PGR Progression Boards are run each year to track PGR progression, viva outcomes, misconduct, suspensions and timeliness of events. With regards to pastoral care, the School has seven experienced senior staff that act as pastoral mentors for PGRs, overseen by and including the DoGE. Any cases that require specialist support are referred to the University's Wellbeing support service who have dedicated PGR provision.

Due to the nature of our research and the proximity of staff to research laboratories, supervisors will typically meet students on a daily basis. More formal meetings are held monthly and notes from both students and supervisors are recorded in SkillsForge. Progression viva voce examinations are held after 9 and 21 months and students are required to present a report detailing their progress and discuss research plans with at least two independent academic staff. For progression to be approved, the examiners must be satisfied that: (i) the student has made sufficient progress intellectually, (ii) data accrual is of sufficient quantity and quality to enable the thesis to be constructed, and (iii) future plans for completing the research are realistic within the timescale of the studentship. Research training needs are also discussed at this stage together with any issues that the students may have with supervision. In cases where problems exist between student and supervisory teams arise, these are typically managed by the second supervisor (all PGR students are allocated two academics for the supervisory team) or the DoGE and if required, the Associate Dean for Research and the Dean. In extreme cases, this may involve a change of project and new supervisory team, but these cases are rare. At all times however, the interests of both the student and supervisors are carefully considered.

We also support students to develop their research and teaching careers through (i) attendance and presentation at conferences (ii) publishing their research and (iii) contributing to undergraduate teaching sessions. With regards to conference attendance, students (and staff) are encouraged to attend one national and one international conference during their studies and the School provides additional funding to support this. Through this REF cycle, the School has directly invested £280k in supporting conference attendance for both students and staff. Attendance is conditional on presenting their research in the form of either an oral or poster presentation. We also ensure that researchers funded on commercial grants are not disadvantaged by contractual confidentiality clauses and several have presented talks (Zonidis, 27th ISHC Kyoto, 2019) and posters [(Wilson, 27th ISHC Kyoto, 2019); (Wallace, 9th ISOP Paris, 2019); (Edgar, Broadbent, Armitage 26th ISHC Regensberg, 2017)] at international meetings. Many students gain experience of presenting either orally or via posters at the annual PGR conference and 3-minute thesis competition. This gives PGRs an opportunity to showcase their research and receive feedback on the strengths and areas for improvement before they present externally. We also encourage students to publish their research prior to the viva voce examination and this is done together with the supervisor who can introduce and guide them through the publication process. Intellectual property is also an important consideration with regards to publication and impact and experienced supervisors will also guide students through this process. Central University support is also available through Research and Enterprise to ensure that intellectual property is protected prior to disclosure.

We also encourage PhD students to see research and teaching as symbiotic and of mutual benefit and to this end, we provide students with opportunities to gain teaching experience. For School

funded students, this is mandatory but it is available to all students. Teaching does not typically involve lecturing but predominantly involves laboratory demonstration, small group workshops/tutorials (with academic staff), co-supervision of undergraduate projects and involvement in outreach activities. Students gain experience of presenting through various routes including the Postgraduate Research Science Society, a student inspired initiative that provides students with the opportunity to present to other students and academic staff in a supportive environment. In addition, students are encouraged to attend and interact with internationally renowned scientists as part of the Schools seminar programme.

(iii) Support for academic staff:
Underpinning the support we offer to our academic and research staff is the general principle that staff should retain autonomy over their research careers and are not compelled to pursue particular research agendas other than (i) to generate high quality research outputs leading to impact upon society and (ii) train the next generation of research active scientists to the highest standards. Huddersfield University is committed to Vitae's Concordat to Support the Career Development of Researchers and as a School and UoA, we provide a variety of mechanisms to ensure that staff are supported throughout their tenure. The Universities Personal Development and Performance Review (PDPR) process provides an opportunity to manage performance and career development on an annual basis. Any barriers to successful delivery of research (and teaching) targets are discussed and plans to reduce the impact of any barriers are developed on a case-by-case basis. In addition to the annual PDPR process, we operate an 'open door' policy where staff can discuss the full range of issues affecting performance with line managers and senior colleagues. Mentoring of staff also occurs both informally (e.g. through collaboration with colleagues in research centres) or more formally through the appointment of academic mentors. Our strategic aim is to create an inclusive research environment and culture where staff are able to achieve increasingly more demanding targets in a manner that is supportive.

As indicated above, the School of Applied Sciences has invested QR funding into PhD studentships and strategically, these are awarded to (i) new staff typically within two years of appointment to help establish/support their research or (ii) established staff that have multidisciplinary research projects. Over the current REF period, the School of Applied Sciences has directly sponsored fully funded studentships (£4.449M) and these provide new staff in particular with an opportunity to get their research off the ground during the early part of their tenure. This support has also been used strategically to build areas of interdisciplinary research within and between research centres. In addition, new staff are not over-burdened with heavy teaching loads in the first year of their tenure and this is done with the aim of establishing their research activities.

Additional support within the School included an annual bid for key equipment required to expand our research activities and over the last REF cycle, the School of Applied Sciences invested a total of £3.775M in new equipment (see section 3). With regards to access to equipment we operate under the general principle that if the School has purchased it, then it is available to everyone (provided they are fully trained to use it). Academic and research staff therefore have access to a wide range of equipment and facilities (see section 3).

At the University level, funding is available on a competitive basis from the Vice Chancellor's Strategic Fund, University Research Fund (URF), the Collaborative Ventures Fund (CVF) and Proof of Concept fund. Within this REF cycle, the School has been awarded £682K from URF to support multidisciplinary research, £415K of which involved a joint project to Build the Foundations for the Institute of Molecular Medicine. This project focused predominantly on harnessing the drug discovery capacity of the School involving staff from all three UoAs submitted to REF2021 (3, 5 and 8). In other examples, a one-off, matched-funding award of £590K was made from the VC Strategic Fund in a collaboration with Essilor for work on functional electrochromic eyewear. We also provide funding for attendance at conference travel through a staff development fund.

(iv) Equality and Diversity:

As described in the institutional environment statement, the University is passionate about equality, diversity and inclusion in all aspects of its business. The Institution has established the University Equality, Diversity and Inclusivity Enhancement Committee (UEDIEC) to oversee the implementation of University EDI related policies, Code of Practice, frameworks and schemes for staff and students. In 2020, the University signed the Race Equality Charter (REC) and is working towards equal representation of women at most senior levels. Other examples of equality work include enhanced support for Black Asian and Minority Ethnic (BAME) students across the Institution. The University is a Stonewall Global Diversity Champion member thereby demonstrating its commitment to supporting LGBT+ and disabled staff and students. These and other institutional level policies (described in the institutional ES) impact upon the composition of committee structures and policy within each School. The University participates in Vitae's 'Every Researcher Counts' to improve equality and diversity for researchers within higher education and EDI is an important aspect of our commitment to the Concordat to Support the Career Development of Researchers and our HR Excellence in Research Action Plan.

The University and the School of Applied Sciences has long been committed to promoting gender equality in science, and this is evidenced by it achieving Bronze Athena SWAN status in 2015, followed by Silver level accreditation in 2018. The School champions good practice and is the highest Athena SWAN award level holder in the University with some of its staff acting as internal consultants or critical friends to other Schools. Many initiatives related to gender equality have been developed and trialled in Applied Sciences and then either rolled out to the whole University or shared with other Schools. The School's Athena SWAN committee expanded in 2018 to become the Equality, Diversity and Inclusion Committee, so that its remit widened to include all aspects of equality work, and this approach was later mirrored by the University as a whole, evidenced by the formation of UEDIEC (described above) which reports directly to Senate. The School constantly strives to create an inclusive and supportive environment for its researchers and makes considerable effort to maintain an excellent mentoring programme, abide by a Core Hours system, support career progression and applications for promotion, develop case-by-case enhanced maternity provision and support in order to maintain research momentum, support flexible working, and provide access to women-only national initiatives such as Aurora (**Harding** and Sweeney).

With regards to preparations for REF2021, the Universities Equality and Diversity Impact Assessment looked at all protected characteristics with regards to the SRR/IR identification selection process but of these, only gender showed an overall impact. Of all the UoA's submitted by the University to REF2021, UoA8 had one of the smallest variances (-1.85%) with 85.2% and 83.3% of males and females identified as SRR/IR respectively. The Equality Impact Assessment (EIA) for UoA8 indicated that the SRR/IR selection process has had little impact upon gender representation. The output selection process for REF2021 was based first and foremost on the quality of outputs as determined by both internal and external review. Where outputs of equal merit were identified, outputs were chosen to ensure diversity of staff was employed. A total of 5 female (17.9%) and 23 male (82.1%) staff were identified as SRR/IR and using the output selection criteria described above, 6 (9.1%) and 60 (90.9%) outputs were submitted from female and male staff respectively. This broadly reflects the gender distribution within this UoA.

3. Income, infrastructure and facilities

Income:

Our income during this REF cycle is £3.602M, up by ca. 2.4-fold from REF2014 (£1.507M). The majority of our income now comes from EU industry, commerce and public corporations (£1.223M, 33.9% of income) with other significant funding coming from UK industry, commerce and public corporations (£974K, 27.1% of income), BEIS Research Councils, The Royal Society, British Academy and the Royal Society of Edinburgh (£663K, 18.4% of income) and UK-based charities (£517K, 14.4% of income). Our portfolio of funding has expanded and diversified significantly from REF2014 with the income generated from EU industry, commerce and public corporation's

sources representing the most extreme change (£1.223M in REF2021 compared to £0 returned in REF2014). This expansion of funding was driven by the colour related work of **Gabbutt** and **Heron** through collaboration with a series of companies with key interests in functional colorants including: Essilor (France), Hoya (Japan), Sony (Germany / Japan), Security Fibres, QinetiQ, Dstl and Arlabion Ltd. This illustrates the importance of this commercially driven research area. Indeed Essilor, now Essilor-Luxottica, have supported the Huddersfield team since August 2012 and which includes 20% academic staff time, fully funded PDRFs and PGRs. Other examples of commercial funding include **Hopwood** whose collaboration, concerning lead in water, with Yorkshire Water has led to £200K of investment, **Morris** collaborating with Biofac (Danish Pharmaceutical Company) and PGR support from AstraZeneca (**Gill**) and Leo Pharma (**Morris**). Our interaction with commercial bodies also embraces government co-funding schemes such as Knowledge Transfer Partnerships (**Campbell**, AB Vista Ltd.) and Access Innovation, [(Leeds City Region, business development of new products and processes) **Heron**, Arlabion Ltd.].

Our income from BEIS Research Councils, The Royal Society, British Academy and the Royal Society of Edinburgh has grown 10-fold since REF2014 and strategically this is an important area of focus for the next REF cycle. Funding from RCUK includes EPSRC via the Materials DTC with studentships supervised by **Molinari** (×4), **Elliott** (×3), **Moran** (×2), **Cooke** (×2) and **Wedge** (x1). **Moran**, **Gill** and **Patmore** have recorded individual success with awards from the Leverhulme Trust including work on iodonium salts (**Moran**, £107.5K) and electrochemical synthesis with iodine compounds (**Moran**, £173k), Total Synthesis of Aconotine (**Gill**, £116.5k) and Electron Transfer Studies between H-Bonded Dimers (**Patmore**, £68.5K).

Looking forward into the next REF cycle, the sustainability of our research is exemplified by recent awards. For example, **Campbell** was awarded £394K (EPSRC Core Equipment Grant EP/V035940/1) for a Home Energy Resources Unit (HERU). Follow-on funding has been awarded to **Heron**/**Gabbutt** by Essilor (£308K), Hoya (£128K) and the Dstl (£138K) to continue their work on functional dyes.

Income generation is a key strategic objective for the next REF cycle and central support for research is provided by the Research and Enterprise (R&E). The Universities 2019-2025 strategy map (SM) has a set of key performance indicators (KPIs) for both Innovative and International research that are designed to drive improved performance and the University Research Committee coordinates our research strategy. In AS, support is available for research grant applications and commercial contracts through the appointment of a research development manager (RDM) and business development manager (BDM). In terms of support for commercial ventures, the BDM oversees all contract development, NDAs, liaison with the Legal department and IP protection, as well as maintaining familiarity with all aspects of available commercial funding and government initiatives specifically aimed to nurture academic/commercial collaboration. New ventures can be supported internally by the seed fund administered R&E, the Collaborative Venture Fund. As an example, this has funded IP protection and in ovo studies for drug discovery programmes (**Rice** >£30K). Staff are encouraged and supported to contribute to the school-wide income target through traditional applications to RCUK, government innovation funding initiatives and to Charities/Foundations. Clear indication of research targets is discussed during annual staff appraisals and support takes the form of, for example, themed research away-days where good practice is disseminated by successful grant holders, grant-writing workshops and provision of funding opportunities bulletins from R&E. Many staff are now coached in garnering and recording impact by internal events (away-days) and external consultants (Vertigo Ventures).

Infrastructure and facilities:
The School has continued to make a major financial commitment to strengthening our in-house research facilities ensuring they continue to remain state-of-the-art. This is enhanced with the £8.3M investment in a new teaching laboratory block which has allowed the conversion and refurbishment of previous teaching infrastructure thereby freeing up more space for research and correspondingly an increase in capacity. This has also allowed the creation of dedicated research student scriptoria. For years 1 and 2 of PhD study these are multi-disciplinary shared spaces allowing for the cross-fertilisation of scientific ideas and collegiality. For final-year postgraduates

there are quiet rooms available conducive to thesis writing. In addition, we have dedicated laboratory facilities within the 3M Buckley Innovation Centre (3M BIC) housing the test-rigs for analysing lead in water pipes with Yorkshire Water (**Hopwood**) and the Zeiss confocal microscopy suite used for inter-disciplinary research focused on drug discovery. Access to high performance computing facilities within the University (and 8 node high performance computing cluster from Icetope located in 3M BIC) is available for both materials and drug discovery-based projects.

The School maintains a strong commitment to instrumentation and the facilities have further increased in number and diversity, allowing access to a wide variety of equipment and a significant reduction in waiting time. Over this REF cycle, the School has invested £3.775M in equipment and £3.282M refurbishing laboratories in the Joseph Priestley building. Access to all instrumentation (as well as solvents, gasses and many consumables) is free at the point of use to promote egalitarian division of funds and acts as an enabler for both establishing and returning researchers. The School houses three dedicated synthetic research laboratories, an air-sensitive laboratory, computational facility, an analytical suite, a thermal methods unit, separate NMR and EPR spectroscopy facilities, and an X-ray laboratory. Molecular modelling infrastructure has been enhanced with the recent purchase of an Intel Xeon Processor E3v5 Family that controls a total of 176 cores with hyperthreads and with 2048GB memory.

The NMR facility comprises of open-access 400 MHz and 300 MHz multi-nuclear instrumentation along with a 600 MHz instrument with a cryo-probe for dedicated technician-controlled analysis. The latter two instruments were recently purchased as part of a £650K-programme to increase NMR facilities. For larger items of equipment (NMR/MS/X-ray/confocal microscopy), a full-time research technician and/or academic has been appointed to run and maintain the facility.
The EPR facility houses a JEOL JES-FA100 X-band spectrometer equipped with a variable temperature system. We also have a dedicated X-ray diffraction facility that houses three powder X-ray diffractometers (benchtop, high temperature and a D8 Advance), a small-angle X-ray (SAXS) and two single-crystals X-ray instruments (dual source Bruker Duo and Advance). The Advance diffractometer was upgraded recently with a new detector (~£60K). Also available for use is an analytical facility that includes 8 HPLC and GC instruments, ion chromatography, capillary electrophoresis, 2 GC-MS and a LC-MS. A bespoke UV-Vis-NIR spectrophotometer with a dedicated xenon lamp irradiation facility to enable variable temperature kinetic analysis of photoresponsive molecules has been purchased as well as Fluorescence (Horiba Scientific Fluoromax-4 Spectrophotometer) and fluorescence lifetime (Edinburgh Instruments Mini-Tau spectrometer (EPL-405)) instruments There is also access to numerous routine ATR-IR, UV-Vis, potentiostats and atomic absorption instrumentation as well as more specialised equipment such as ICP-MS (and OES), DSC, TG, electron microscopes, a hot-stage microscope, surface area analyser and X-ray fluorescence spectrometers.

IPOS provides analytical expertise to both businesses and academics within Applied Sciences and across the University and is a focus for analytical research with facilities that include LC/MS, GC and GC-MS, ICP-MS, GPC-MALLS, ion chromatography and elemental analysis (Exeter Analytical CE440 Elemental Analyser). IPOS deliver both the mass spectrometry service (Q-TOF) and the elemental analysis for the School. Furthermore, they also offer method development of LC-MS, anionic ion chromatography and general chromatography expertise.

As stated earlier, the School operates on the basis that its equipment and facilities are made available to all staff. This covers all areas of activity within the School (UoA's 3, 5 and 8) and these facilities are illustrated in the organisational figure in Section 1. Due to the cross-disciplinary nature of the School's research, Chemical Sciences also has access to both Biological and Pharmaceutical facilities (such as cell culture, molecular biology and pharmaceutics). For drug discovery-based research, this allows a direct line-of-sight for the drug development pipeline from target identification → chemical synthesis → pharmacological evaluation → patient treatment.

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

Collaboration:
Collaboration with academics and commercial partners is at the heart of our working and our collaborative links span the globe. It has been an essential strategic element of our success in achieving our objectives as laid out REF2014 and described in section 1. The extent of our collaboration with international partners and academic/corporate partnerships is reflected in the SciVal analysis of UoA8 outputs conducted between 2014 and November 2020. Outputs including international partners represent 38.5% of all our publications and 8.4% of our outputs include corporate partners. Collaboration with international partners also extends to patent applications generated within this REF cycle. Notable examples of our international collaborative work include:

- The established collaboration with the international medical device company Essilor (**Gabbutt**, **Heron**) has led to a family of international patents on electrochromic materials [PCT Int. Appl. (2018), WO2018127540; (2017), WO2017005824; (2015), WO2015040031]. In the area of functional materials **Heron** has a longstanding collaboration with Gentili (spectroscopy, artificial intelligence, Perugia) wherein UoH design dyes which are harnessed in fuzzy logic systems (Chem. Comm. 2016) and serve as artificial neuron models (Angewandte 2017). Computational provision guiding work on photochromic dyes (Chem. Comm. 2014) has been developed with **Heron** and Jacquemin (computational chemistry, Nantes) and theoretical studies concerning solar cell dyes with Ju (computational chemistry, Nanjing University of Science and Technology).
- **Elliott**, who was recently highlighted as one the emerging leaders in inorganic photochemistry [Inorg. Chem., 2016; (https://pubs.acs.org/doi/abs/10.1021/acs.inorgchem.6b02830)], has a collaboration with Toulouse University (Dixon, Inorg. Chem. 2020).
- **Du**, in collaboration with The Hong Kong Research Institute of Textiles and Apparel (Hong Kong Polytechnic University), was awarded a gold medal by the 46th International Exhibition of Inventionas of Geneva (2018) in recognition for research concerning 'Textile Waste Recycling by Biological Methods'.

Expanding our international reach is an integral part of our 2018-25 strategy map and through central University support, finances are available to enable academics to travel to global QS300 institutions with the aim of (i) promoting our expertise in Huddersfield to other institutions and (ii) generating new research projects that will generate income and deliver high quality outputs and impact.

On the national stage, examples of established collaborations include: **Rice** has longstanding collaborations with Cardiff (Pope, Dyes & Pigments 2020) and Warwick (Ward, Angewandte 2020). **Patmore** collaborates with Halcrow (Leeds, Chem. Sci. 2015) and Meijer (Sheffield, Chem Comm 2016). In the area of TM complexes **Elliott** collaborates with Weinstein (Sheffield, Inorg. Chem. 2018) and Gibson (Newcastle, Dalton Transactions 2017). In computational chemistry **Molinari** collaborates with Symington (Bath, J Phys. Chem. C 2020). **Campbell** has a long-standing collaboration with the AB Vista company (O'Neill, Food Chemistry 2020).

Within UoA8 and the School more broadly, our research strategy is designed to promote interdisciplinary research and collaboration and this will continue to be a key component of our strategic approach in the next REF cycle. We recognise that in order to obtain research income and generate research with impact, teams of researchers with different expertise need to be assembled to form 'wolf packs' as opposed to 'lone wolf' operations. Our research centres will continue to drive this change in our research culture to develop and support interdisciplinary collaboration.

Contribution to the research base, economy and society:
Staff within this UoA are committed to the dissemination and promotion of their research to the wider scientific community through such activities as the delivery of invited lectures at international and national conferences (including organisation thereof), peer reviewing for journals and grant awarding bodies. Illustrative examples are given below:

Editorial positions: Staff have undertaken Guest Editorships of special issues including Inorganics (**Elliott**), Environments, Resources (**Dimakis**) and Molecules (**Morris**). Editorial Board memberships include: Carbohydrate Research (**Laws**), Bioresearch Communications, PLOS One (**Du**), Food Hydrocolloids, Food Biophysics, European Biophysics Journal, Molecules (**Morris**), Journal of Cereal Science, Food and Bioproducts Processing, Foods (**Campbell**), Arkivoc (**Hemming**), The Scientific World Journal (**Moran**) and Chemistry (**Rice**). Editorships are held for Journal of Chemical Research (**Gabbutt**), RSC Specialist Periodical Reports: Organometallic Chemistry (**Patmore**, **Elliott**). **Heron**, Editor-in-Chief of Dyes & Pigments, has overseen the direction of the journal through selection of editors/editorial board members over the last 13 years which has returned a steady increase in impact factor to 4.61 (2020).

Plenaries and invited lectures: External recognition of our work is evident in the growing number of invitations to speak at national and international events. During the current REF period there have been 3 plenary / keynote lectures, 32 invited lectures at international conferences and 25 invited lectures at national meetings.

Committee membership & grant reviewing: Several staff serve on learned/national society committees, including: (i) The Royal Society, with membership of the International Exchanges Committee/Panel (**Wedge** & **Patmore**), the Commonwealth Science Conference Committee (**Patmore**) and the International Exchange panel (**Patmore**); (ii) The Royal Society of Chemistry with vice-chair and chair of The Thermal Methods Group (**Parkes**) and membership of the same (**Harding**), the Supramolecular Chemistry Award committee (**Rice**), the Carbohydrate Group 2012 – 2019 (**Morris**), Accreditation and Validation of degrees (**Hemming**) and North-East Region Steering committee (**Moran**) and local sections (**Moran** (former chair) & **Molinari**); (iii) the Society of the Chemical Industry [Young Chemists' Panel 2013-2017 (**Moran**)]; (iv) British Mass Spectrometry Society National Executive Committee 2019-202 (**Harding**); (vi) International Society on Heterocyclic Chemistry Nomination Awards Committees (**Hemming**). Additional committee memberships include: International Evaluation Committee for the ERA-NET Cofund ICT-AGRI-FOOD call (**Campbell)** and committee member of HEC Materials Chemistry Consortium (**Molinari**).

Staff make an important contribution to grant reviewing for national RCUK (EPSRC, BBSRC, MRC) and charitable organisations (Guy's and St Thomas' Hospital Trust, Royal Society) and international [NWO Domain Science (Netherlands), French National Research Agency, American Chemical Society Petroleum Research Fund, Hungarian Research Council, Swiss National Science Foundation, National Science Centre (Poland), Innovation Technology Commission (Hong Kong), Ministry of Science and Education (Spain)] bodies. **Patmore** is a member of the Royal Society's Research Grants Board (physical sciences) 2019 – present and **Moran** and **Gillie** are full members of the EPSRC Peer Review College. **Heron** was an EU Expert Evaluator (2018) for the Marie Skłodowska-Curie Individual Fellowships.

Conference organisation: **Campbell** organised the Innovations in Aerated Food Processing for Sustainability, Health and Life meeting/workshop (Chipping Campden, UK) and **Morris** co-found and organises the Biennial UK Hydrocolloids Symposium series. The 1st International Symposium on Dyes & Pigments (Seville 2019) was organised and chaired by **Heron**. Staff contributions were noted to both national and international organising scientific committees (23) for established symposia; **Wedge** serves as committee member and webmaster for the RSC ESR group responsible for organising the largest European conference dedicated to ESR spectroscopy. **Du** served on the organising committee for 23rd and 25th Annual Conferences: Sustainable Energy and Manufacturing the Future SCI's Chinese UK Regional Group.

Public engagement: The Schools of Applied Sciences have run a public lecture series throughout the current REF cycle and in 2019. It is currently being run as a partnership between the two Schools with the aim of communicating research conducted primarily at Huddersfield (with some guest external speakers) to the general public. This successful program of seminars has been running for many years and remains popular with the public. In addition, staff have presented their research at Café Scientific and Pint of Science events. The School also participated in the University's 2016 and 2017 European Researchers Night events (funded by the European Commission under the Marie Skłodowska-Curie actions) with over 3,000 visitors of all ages exploring research at the University. The School also has a bespoke outreach programme, which contains a portfolio of scientific activities aimed at local schools, which enables 15-18 year-old pupils to experience laboratory work and has in the last two years involved over 30 schools. Our role in the local education community has been enhanced from 2019/20 by our recently completed laboratory block which houses a dedicated and bespoke schools liaison facility/outreach laboratory. This is used to house a series of GCSE and A-level practical sessions given to schools/colleges to support their chemistry provision and as recognition that laboratory sessions form a fundamental part of the scientific training.

Economy and society: Throughout this document and in our suite of impact case studies, reference is made to our contributions to the economy and society. Notable examples include the work of **Heron** and **Gabbutt** (Essilor), **Hopwood** (Yorkshire Water) and **Campbell** (AB Vista). In addition, IPOS was the only section of the University to remain open throughout the Covid pandemic to conduct essential analysis of pharmaceutical products for local industrial partners.