Institution: University of Glasgow
Unit of Assessment: 10, Mathematical Sciences
1. Unit context and structure, research and impact strategy

1.1 Unit context

The School of Mathematics and Statistics at the University of Glasgow (UofG) spans all three fundamental areas of the mathematical sciences, with research and teaching strengths in Applied (21 FTE) and Pure Mathematics (18.8 FTE) and Statistics (20.1 FTE) (described as groups). The phenomenal growth of our Unit since the REF2014 by 50% (59.9 FTE submitted compared to 41 FTE in 2014) has allowed us to solve fundamental mathematical problems with results appearing in prestigious journals such as Annals of Mathematics, Inventiones, and Annals of Applied Statistics, while pursuing new applications of mathematical and statistical modelling in health-care technology and in environmental sciences and ecology. We lead 3 EPSRC funded research hubs and are partners in one centre (with total funding awarded exceeding £5M) including the Centre for Mathematics in Healthcare (SoftMech), the Statistical Emulation and Translation in Healthcare hub, a multi-centre research collaboration with MIT and POLIMI, and a Research Centre on closed-loop data science. Our research is delivering global impact in diverse areas such as animal pain, radiocarbon dating and ground and surface water and air quality. Our research diversity is reflected in Figure 1 emphasising our commitment to fundamental research in the Mathematical Sciences across Pure and Applied Mathematics and Statistics and to cross-disciplinary and applied research that delivers impact. Figure 1 identifies a number of distinct Unit themes and specific strengths (based on fluid staff groupings) to encourage and strategically support exchanges of ideas, methods and applications across all three groups and designed to afford maximum research flexibility.

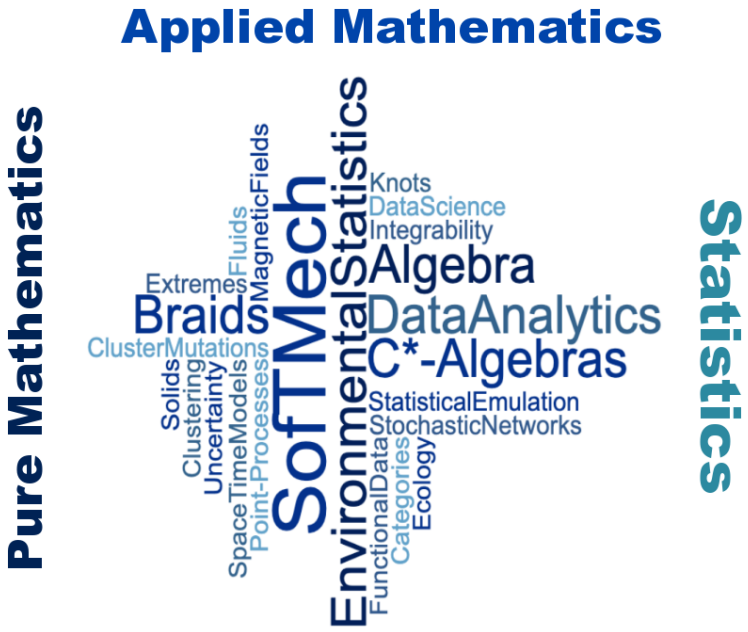

Figure 1. Research areas and themes

We are a major international Mathematical Sciences research centre attracting excellent researchers globally at all career stages (20 early career and 13 internationally established research leaders appointed since REF2014; see Section 2). Our hiring strategy, which embeds ED&I in pursuing breadth and depth in the mathematical sciences has enabled us to respond to a multitude of emerging research challenges (Section 3) which is reflected in our rapidly growing grant income, which has tripled over the REF period (Table 1), and the growth in our Postgraduate Research (PGR) student numbers by 54% (48 registered in 2014 to 74 in 2019/20, with 41% BAME, 8% registered disabled and on aggregate 42% female). This is a steep upward trajectory, with PhDs awarded

increasing from 9 p.a. (2014) to 14 p.a. (2019/20). The excellence of our Unit is further evidenced by the national and international roles our staff play in setting the Mathematical Sciences agenda, in the London and Edinburgh Mathematical Societies, the Royal Statistical Society, the Royal Society of Edinburgh and the Institute of Mathematics and its Applications (IMA). Our colleagues have been globally recognized for their scholarship through the Timoshenko, Dilwyn and Crighton Medals, the Whitehead, Adams and Barnett prizes, elections to the AMS fellowship and a CBE (see Section 4).

Our accomplishments are directly attributable to (a) strategic investments from the University in new appointments (see above) as well as a £10 million investment in a bespoke building (Section 3), (b) our sustained investment in PhD students and fellowships and (c) our leadership of collaborative interdisciplinary networks.

	13/14	14/15	15/16	16/17	17/18	18/19	19/20
FTE (R&T)	41	42	46.5	49.6	53.6	55.93	59.93
Awards in £1M	1.23	1.13	1.8	1.93	3.55	3.13	4.26
PGR students	48	60	63	60	61	62	74

Table 1. Growth in FTE, proportioned award value and PGR numbers

REF2014 strategic aims

Our strategy presented in REF2014 was to enhance the position of the School as a broad-based, internationally leading and research-led institute. Specific objectives were:

a) growing and supporting our staff, and making strategic appointments at all levels;
b) ensuring that we have a world leading infrastructure and base for growth, while fostering interdisciplinarity;
c) increasing recruitment of research students, and growing our PGT programmes.

We had striking success with all three objectives. We have supported nine of our colleagues in their promotions to professor, a testament to our developing talent strategy. We have attracted outstanding external appointments to 3 chairs in Pure and Applied Mathematics and Statistical Sciences as well as making early and mid-career appointments (5 in applied mathematics, 8 in pure mathematics and 7 in statistical methodology), a testament to our external reputation. We have achieved significant grant successes, for example, SofTMech and the new EPSRC Hub for Statistical Emulation and Translation, a partnership in a programme grant in Algebra and leading environmental modelling awards (EPSRC WEFWEBs).

Further details

In **Statistics** we have hired an additional 10 FTE (an increase of 50%) to strengthen our capacity, in particular in data science, and as a result we are one of the largest UK statistics groups (external leadership appointment of Illian to the Chair of Statistical Science, 2019, promotions of Lee (2018) and Miller (2019) to professor and recruitment of 7 ECRs since 2017). Staff have been recognized internationally with the Frank Hansford-Miller Award (Bowman, 2015), the Abdel El-Shaarawi Young Researcher's Award by the International Environmetrics Society (Miller, 2018), the Suffrage Science Award for Mathematics and Computing (Neocleus, 2019) and the Barnett Award of the RSS (Scott OBE, 2019).

This strengthening of capacity is part of our strategy to pursue statistical methodology that is motivated by global challenges and to deliver high-impact solutions through forging links within the Unit (e.g. Mathematical and Statistical Ecology, Mathematical Sciences in Healthcare) and across disciplines. Our methodological focus includes spatiotemporal models, point processes, and functional data analysis. Our new appointments in data analytics and data science bring expertise in statistical emulation (Swallow), clustering and networks (Anderson, O'Donnell) and extremes and computationally efficient inference tools (Castro Camilo, Niu). They have also allowed us to grow the **Mathematical and Statistical Ecology** theme within the Unit, led by Cobbold and our new

appointment Illian, which is further supported by 3 new appointments (Torney (2016), Swallow (2019, Niu (2019)). Supporting this theme will improve cross-unit research and stimulate new impactful research (see Section 1.2 below).

In **Applied Mathematics** our strategy has been to build extensively on our expertise in Continuum Mechanics, embedding our research on blood circulation and soft biological tissue modelling into the world-leading interdisciplinary 2016 **EPSRC Maths-in-Healthcare Centre for Multiscale Soft Tissue Mechanics (SofTMech)** with 14 investigators led by Hill, Luo FRSE and Ogden FRS, a renowned expert in solid mechanics and a recipient of several major prizes (Timoshenko Medal, IUTAM/Elsevier Rodney Hill Prize in Solid Mechanics). The Centre includes statisticians (Husmeier, Niu, MacDonald), clinicians and medical scientists and has strong partnerships across the UK and with industry. We made key appointments in the areas of solid-mechanics/fluid-dynamics and Mathematical Biology (Stewart (2013), Penta (2017) and Gao (2019)) which supported the winning of a major **EPSRC Centre-to-Centre partnership grant** (2020, £870k) for collaboration with MIT and the Politecnico di Milano (POLIMI) widening the scope of SofTMech research and its international impact. The already existing interdisciplinary links with statistics will be significantly expanded through a £1.5M grant for an associated **Hub on Statistical Emulation and Translation** (Husmeier, 2020). Further investments in applied mathematics included the strengthening of the MHD group (MacTaggart (2015) and Teed (2017)) and the leadership appointment of Mottram (2020) to further strengthen and diversify our capacity in mathematical modelling with the aim to develop future links with industry.

In **Pure Mathematics** our strategy has been to retain internationally recognized areas of excellence, such as in algebraic facets of symmetry, while developing new research connections with analytic and geometric structures, as well as re-establishing expertise in number theory. Leadership in Pure Mathematics has been greatly strengthened by the external appointments of Wemyss (LMS Whitehead Prize, Adam Prize, Early Career EPSRC fellowship) to the Chair of Mathematics in 2016 and Li (ERC Consolidator Grant) to the Chair in Mathematical Analysis in 2020 as well as internal professorial promotions. Wemyss is a Co-Investigator of the EPSRC programme grant **Enhancing Representation Theory, Noncommutative Algebra and Geometry Through Moduli, Stability and Deformations,** which is the first ever programme grant with algebra at its heart. This brings new coverage of algebraic geometry and connects it to research themes in geometric representation theory (Bellamy, promotion to chair 2019), low-dimensional topology and group theory (Brendle, promotion to chair 2016) as well as developing new ties in arithmetic geometry with recent appointments in number theory (EPSRC Early Career Fellow Bartel 2017, promoted to professor 2019, Sofos 2019).

Since 2014 we have grown our capacity in analysis (specifically operator algebras) to become the largest in the UK, led first by White (promotion to chair 2016, Humboldt fellowship, now professor at Oxford) and now by Li (Chair of Analysis 2020, ERC Consolidator Grant). Li, White and Zacharias made a leading contribution in the international effort of classifying nuclear C*-algebras, while Voigt, Whittaker provide expertise in noncommutative geometry and dynamics interlocking with other research themes including geometric group theory (Brendle) and Teichmüller theory (Gadre 2016, Fortier Bourque 2018) and ring theory (Brown).

To create further interdisciplinary links between algebraic topology, algebra and geometry as well as mathematical physics and integrable systems, we have made 8 additional appointments (Davison, Fortier-Bourque, Gadre, Gratz, Lecuona, Stevenson, Valeri, Wand) since 2014.

1.2 The Future

Our aim is to undertake fundamental research needed to address significant societal issues and scientific challenges. To realise our vision we will continue to invest in people across the Mathematical Sciences, be proactive and responsive in shaping our research themes, further stimulate our interdisciplinary research and impact, grow our postgraduate and postdoctoral communities and shape our estate by developing and extending our building.

Aim 1. Strengthening existing and growing new research themes

- Our new Analytics, Inference, Impact and Innovation Initiative (AI^3) will support research that transforms the practice of **Statistics, Data Analytics and Data Science** by bringing together our research in functional data analysis, spatio-temporal modelling, computational statistics, Bayesian inference and network analysis and their applications.
- In Applied Mathematics and Statistics, we will further strengthen the link between **Mathematical and Statistical Ecology** through research on spatial point processes, Bayesian inference and artificial intelligence, while enhancing collaborations with the Boyd Orr Centre of Population and Ecosystem Health and the Institute for Biodiversity, Animal Health and Comparative Medicine.
- In Applied Mathematics and Statistics we will build on the success of the SofTMech Centre and the Hub for Statistical Emulation and Translation, to grow our fundamental research in all aspects of soft tissue mechanics, physiological fluid-structure interactions, statistical machine-learning and emulation applied to **Mathematical Healthcare** with the aim to translate our research into clinical trials.
- In **Applied Mathematics** our appointment of Mottram (2020) to a chair in Applied Mathematics is part of our succession planning to maintain a leadership role in mathematical modelling and fluids in particular. We will capitalise on Mottram's experience in collaborations with multinationals (Merck Chemicals, Hewlett-Packard) and SMEs (Envisics, Kirkstall) to substantially increase our knowledge exchange with industry.
- In **Pure Mathematics** we will expand our expertise in Algebraic Geometry (Wemyss), Geometric Group Theory (Brendle) and Number Theory (Bartel, Sofos) connecting growth in these themes to our UK-leading strength in algebraic research (Bellamy, Brendle, Brown), fusing a historical strength with modern methods to forge connections across pure mathematics.
- We will further develop and strengthen the interdisciplinary links between **Integrable Systems and Mathematical Physics** with pure mathematics including geometry, representation theory and algebra.

Across all research themes within the Unit, we will make new staff and leadership appointments (including a professorial appointment in Statistics and Data Analytics for succession planning). We will continue our growth in staff with a goal of a further 25% increase and our PhD recruitment with a goal of a 50% increase, over the next 5 years. We have already secured £1.3M of investment from the University to accommodate future growth of our Unit.

Aim 2. Supporting interdisciplinary collaborations and delivering Impact

Our conviction that mathematical sciences are key to tackling major multi-disciplinary research challenges drives our underpinning theme of cross-disciplinary research. We have built networks with external partners from industry and business, government and non-governmental organisations and agencies as well as academic networks ensuring our continuing success to deliver impact.
We have won support for cross-disciplinary research and impact from a variety of sources, including cross-disciplinary PhD studentships (e.g. UofG Lord Kelvin Adam Smith (LKAS) scheme, NERC DTP Iapetus I and II, STFC and ESRC funding), institutional KE funds and Impact Accelerator Accounts (EPSRC). The Unit has invested strongly in leadership to develop cross-disciplinary research and impact: we have appointed a senior member of staff as impact champion, who is also a full member of the Unit's management committee, and two Industrial Advisory Boards, which strengthen existing and facilitate new collaborations with partners to further enhance our impact**.**

Impact activities: Our 5 impact case studies are based on long-standing collaborative partnerships with the environment agencies (EA and SEPA), Public Health Scotland, Shell and Vetmetrica (a veterinary IoT SME). We nurture these partnerships through training workshops for the partners' staff, student and staff placements, and our staff serving as advisors. We actively pursue opportunities to work with others and support such activities financially and administratively. Workshops are often based on our open access software including CARBayes (Lee, 119K downloads in the REF period), CARBayesST (44K downloads) and GWSDAT (Bowman, Evers), software developed in collaboration with Shell. Our Unit delivers societal impact through outreach events (our distinguished lecture series and workshops described in Section 4) and taking the lead

in national STEM public engagement as well as training workshops for continuing professional development (CPD).

Future pathways to impact

Through our strategy of developing cross-disciplinary research we have identified a number of future impact case studies that we will support financially (e.g. hiring Postdoctoral Research Assistant/Associate (PDRA) support, workshop funds), academically (through recognition in the Unit's workload model) and administratively (e.g. gathering evidence of impact). The impact pipeline is drawn from all themes of our Unit, is supported by an impact champion (Stewart) and includes:

- **The development of similarity-sensitive measures of biodiversity** (Cobbold) where a recently developed plant biodiversity simulator is being used to investigate the predicted effect of landscape decisions for peatland restoration with Peatland ACTION for Scottish Natural Heritage. Partners include the Natural History Museum (NHM).
- **Applying machine learning to conservation images** (Torney) to assist with the monitoring of animal populations. Deep Learning has been applied to automate the counting of wildebeest in the Serengeti in collaboration with the Tanzanian Wildlife Research Institute (TAWIRI), Frankfurt Zoological Society, and the Friedkin Foundation.
- **Statistical learning and discrimination in Forensic Science** (Neocleous) develops models and easy-to-use software for evidence evaluation and classification. Partners include the Netherlands Forensic Institute, the Swedish Statens Kriminaltekniska Laboratorium and the Polish Institute of Forensic Research. This project is currently being supported by the Unit in the form of a PDRA to assist with software development.
- The design of **efficient numerical algorithms based on Laguerre diagrams** (Roper) is currently investigated in collaboration with Heriot-Watt University and a research group of Tata Steel Europe. The aim is to generate realistic candidate microstructures for use in the modelling of steels and other alloys.

Aim 3. Supporting our staff and growing our postdoctoral and PGR communities

At the heart of our strategy are our investments in our staff, postdoctoral appointments and postgraduate students.

Staff: We will work towards fulfilling the potential of our staff as international research leaders. We have developed a mentoring programme by senior academics, we support training (e.g. participation in the Scottish Crucible and the University Leadership Development Programme), we provide financial support for conference and workshops, both for attendance and organisation (e.g. the joint BMC-BAMC 2021) and we fast track promotions of outstanding internal candidates.

Postdoctoral: Through our grant success we have since 2014 increased the number of research only staff by 167% (currently 18.7 FTE for 2019-20 with 26.5% being female). We will prioritise further investment in early career researchers through our 3-year Rankin-Sneddon fellowship scheme (4 appointments since 2019) and support our postdoctoral community through mentoring, training events and workshops as well as the UofG Researcher Development Programme.

PGR recruitment: We will build on our success in PGR recruitment by continuing the Maclaurin Scholarship Scheme, giving every year, 2-3 outstanding PG students five years of funding together with teaching experience. In addition, we have a targeted graduate teaching assistant scheme for existing PhD students who wish to gain teaching experience (usually over a 6-month period). We are also building on industry collaborations to support our recruitment. We have been active in pursuing CDT funding applications (successfully reaching the interview stage) and will continue to be responsive to opportunities given our recent grant success. We will support our PGR community through provision of general skills training and dedicated national training including SMSTC and APTS and by encouraging them to present at conferences.

Aim 4. Progress towards an open research environment

We actively prioritise open access research: all publications are made available by posting them on *arxiv.org* or on the University's own repository Enlighten. Data generated in the course of our research is made openly available through University support or funder repositories (e.g. NERC data

centres). Open access software (e.g. CarBayes, RShiny apps) from our research is disseminated via CRAN or GitHub. Currently more than 98% of our staff have ORCIDs.

2. People

2.1 Staffing strategy, recruitment and policy

Overview

We motivate and empower all our staff by providing the skills and opportunities to lead future developments in the mathematical sciences. Our staffing and hiring strategy is driven by our vision of excellence and strengthening interdisciplinary links in our Unit. It is based on the following principles:

- Recruiting excellent staff, based on research publications and income, expertise in new areas, strengthening of interdisciplinary links, as well as the potential to provide future leadership.
- Growing talent within the Unit by investing in our support mechanisms, e.g. our generous travel support for staff or through sabbatical leave.
- Increasing diversity by sustaining our track record of appointments that have increased the diversity among our staff, growing underrepresented groups in the mathematical sciences. For example, currently 29% of our professorial staff are female compared to the UK average of 11% according to the latest 2017 Benchmarking Study of the London Mathematical Society[1].

Since REF2014, the unit has grown from 41 to 59.9 FTE with new appointments across all areas of our Unit and at both, senior and early career stages (we now have 32% ECR staff from 14% in 2014, but retain a healthy career profile across all grades (Figure 2)), balancing necessary leadership and future succession planning.

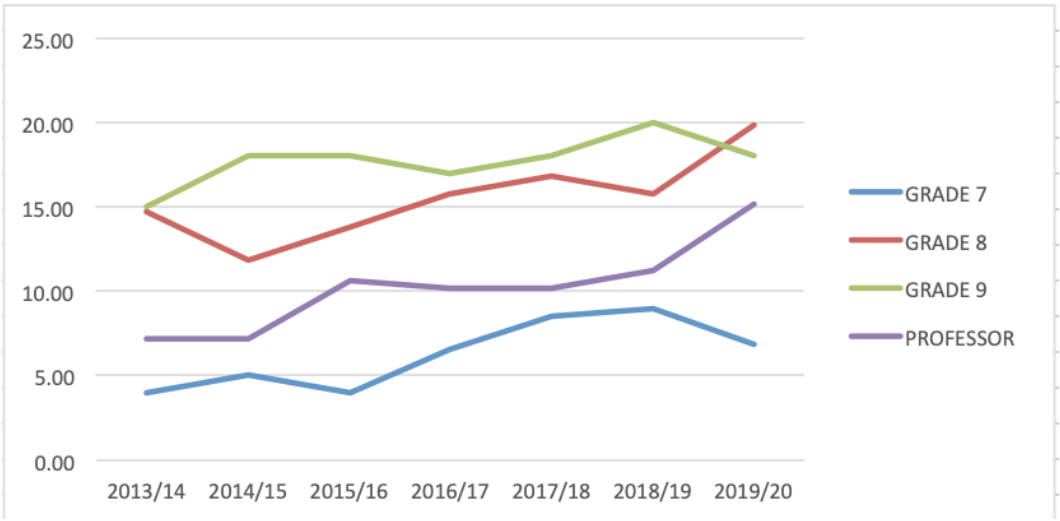

Figure 2. R&T staff growth by grade

[1] Carried out by Ortus Economic Research Ltd on behalf of the LMS - Table 7: https://www.lms.ac.uk/sites/lms.ac.uk/files/files/Benchmarking%20Report%20FINAL.pdf

We target specific research themes of interest (see Section 1.2) but are flexible based on the field of applicants. Since 2014 we have made appointments that cross research themes: Number Theory and Arithmetic Geometry (Bartel, Sofos), Mathematical Physics and Algebra (Valeri), MHD (McTaggart, Teed), soft tissue modelling (Gao, Penta) and Mathematical and Statistical Ecology (Illian, Kosta, Torney, Swallow). External professorial appointments in Pure Mathematics (Li, Wemyss), Statistics (Illian), and Applied Mathematics (Mottram) and internal promotions (Bartel, Bellamy, Brendle, Cobbold, Korff, Lee, Miller, White, Zacharias) have strengthened leadership for our research themes.

Staff development strategy
At each career stage, we aim to support our staff in their development with emphasis on a collegiate research culture supplementing the UofG Researcher Development Programme.

Postdoctoral staff. We strongly adhere to the national Concordat to Support the Career Development of Researchers by implementing a supportive Performance and Development Review (P&DR) offering help and advice throughout the year, ensuring all research staff are mentored and by providing tailored and subject specific online resources and training workshops.

Career development for all staff is supported through the P&DR reviewer relationship and informal mentoring by experienced staff. We encourage collegiality through shared PGR supervision, grant writing advice from staff with panel experience and by proposing colleagues for membership in learned societies or funding panels to help with growing esteem. We support staff by providing mock interviews and making previous grant applications available. The success of these measures is reflected in a growth of senior grades within our Unit (Figure 2), for example an increase from 17.5% to 25% of professorial staff since 2014.

Support for Early Career Researchers (ECRs)
All ECRs are assigned a mentor, an experienced colleague who is different from the reviewer conducting the annual P&DR appraisal. While emphasis in both instances lies on the supportive nature of these sources for advice, the additional mentorship provides support for day-to-day problems. This dual system is of great benefit in staff retention and underpins the collegiate atmosphere of our Unit.

ECRs are also supported through the University's Early Career Development Programme (28 staff were or are participating) and a number of bespoke training workshops (e.g. writing EPSRC First Grant proposals and fellowship applications) and through peer review. We also encourage staff to attend the *Crucible,* an interdisciplinary event at local University and Scottish HEI level, where novel research collaborations are explored, as well as monthly College research mini-symposia. We prioritise ECRs in PGR allocation and ensure supervisory support by pairing them with experienced co-supervisors.

New appointments are given a reduced (2/3) teaching load for either 2 or 3 years (depending on experience) to allow them to develop their research (e.g. grant applications, manuscripts, conference attendance). This teaching reduction is extended throughout probation.

Supporting the next generation: Rankin-Sneddon fellowships
In order to support and attract new talent, the Unit created in 2017 from its own annual budget, the 3-year Rankin-Sneddon fellowship scheme for recent PhDs. These give the successful applicants a period to establish an independent research profile. The fellowships allow our Unit to react quickly to new research developments and foster new collaborative links inside as well as outside the Unit.

Supporting new staff members
Our Unit takes pride in its welcoming and friendly atmosphere, which starts with the interview process, where applicants are able to mix with colleagues following their presentations. On appointment, new staff are welcomed to our Unit through meetings with HoS and other senior staff, as well as informal meetings with their appointed mentor and colleagues. Our weekly seminar series

and informal reading groups, which are often preceded and/or succeeded by social activities encourage staff integration. Our new building with its dedicated meeting areas for staff and PGR students plays an essential supporting role in these activities, as does our practice of teaching in teams.

Motivating, empowering and supporting staff

Our Unit operates a workload model monitored annually and adjusted quarterly to provide an open and transparent system to balance research, teaching and administration. Every effort is made to combine teaching and administrative duties in a single semester to enable staff to devote a significant period of the year to research. In addition, the Unit has a generous sabbatical policy for all staff: periods of study leave vary between 6 months and 1 year, with applications submitted annually to the Unit's Research Director. The Unit has approx. 10% FTE on study leave in any given year. The Unit provides annual funding in excess of £250K to support staff and PGR students (excluding research equipment**)** in 3 streams of activity (Table 2). These are in addition to the funds used to support specific PGR training including APTS, SMSTC and attendance at BMC/BAMC. Each staff member and PGR student is eligible to apply for these funds. Additional year-end funds are often available to support additional IT (equipment) updates (as happened in 15/16 and 18/19).

Expenditure	13/14	14/15	15/16	16/17	17/18	18/19	19/20	Average
Annual Budget (£)	265K	272K	264K	292K	299K	299K	314K	286K
Seminars	12%	12%	11%	9%	8%	11%	10%	10%
Staff Travel	22%	22%	29%	21%	24%	23%	13%	22%
PGR Travel	8%	14%	16%	13%	14%	15%	9%	13%
IT	42%	42%	60%	38%	21%	57%	39%	43%

Table 2. Research expenditure

The Unit further supports staff through both University Leadership and national training programmes, e.g. Aspiring Leaders, Academic Leadership, Senior Research Leaders (6 participants) and the LFHE Aurora Leadership Programme (2 participants), which has resulted in promotion success.

Facilitating excellence

The Unit has a research director who chairs the Unit's research committee, and oversees a system for encouraging high quality outputs, grant applications and impact to support the academic development of all staff. This is based on three teams of three senior staff, one from each subject area. The role of these teams is to actively support staff, for example, through informal one-on-one meetings, highlighting and encouraging grant applications as opportunities arise and bringing individuals together for interdisciplinary collaborations. These arrangements have contributed to an increase in our research income (see Table 1 and Section 3).

2.2 PGR Training and supervision support

Since REF2014 we have grown from 44 to 71 doctoral degree students (24 students recruited for 2019-20) with an average 42% being female (Table 4), well above the 26% of the latest 2017 UK National Benchmarking Study[2]. According to a 2019 survey of postgraduate students (PRES2019[3]) we score particularly high in student satisfaction in the categories of Supervision (95% compared to the RG average of 88%) and Resources (95% compared to the RG average of 86%) with an overall satisfaction rate of 91% compared to the RG average of 85%. This is reflected in the timely completion of PhD projects within the normal 4-year period between start and award (see Table 3).

[2] "2017 National Benchmarking Study" prepared by *Ortus Economic Research Ltd* for the London Mathematical Society; Figure 6: https://www.lms.ac.uk/sites/lms.ac.uk/files/files/Benchmarking%20Report%20FINAL.pdf

[3] https://www.advance-he.ac.uk/knowledge-hub/postgraduate-research-experience-survey-2019

	13/14	14/15	15/16	16/17	17/18	18/19	19/20
PhD new starts	14	23	14	18	22	17	24
PhDs awarded	9	11	13	13	13	20	14

Table 3. PhD students starts and degrees awarded.

The Unit's new building has transformed our students' interactions, intellectually (through facilitating interactions between the different areas of the mathematical sciences) and socially by bringing them closer together via dedicated PhD student space. This is evidenced by the survey results: 100% of our students are highly satisfied with the provision of suitable workspace, computing resources and facilities provided by our Unit. During the lockdown and the ongoing COVID19 restrictions we have supported students through IT equipment (e.g. to borrow laptops and workstations for home use).

Funding mechanisms and initiatives for PhD students

Our Unit received in the REF period on average 3 EPSRC DTA funded places and at least one College of Science Engineering Scholarship per annum. We also nominate our best undergraduate students for Carnegie Scholarships and have a record of success: typically, we have at least one such student per year. Other funding sources include the China Scholarship Council, Biometrika, SENSORS, SAAS, Shell, Glaxo-Smith Kline, Royal Bank of Scotland, Toshiba Medical Visualization Systems, McDonnell Foundation as well as self-funded students on scholarships from overseas institutions (2-3 per year). The College also co-sponsors industrial studentships and currently two students are on this scheme.

From our own funds, we have supported a **new scheme, the Maclaurin scholarships** enabling students to fund their PhD through teaching. We recruit 2-3 such students per year. Students on these scholarships have an additional year because of teaching duties and are carefully supported in both their teaching and research activities.

We have sought to grow our PhD cohorts through applying for CDTs and have soft launched the Algebra PhD (GlaMS) programme (with Edinburgh and Heriot Watt Universities). We will continue to respond to opportunities as they arise. The Unit is a full partner in the NERC IAPETUS Doctoral Training Programme.

Diversity of our PhD student cohort

To support our recruitment of overseas students and to increase diversity, we have introduced a 1+3 PhD scheme, where students are recruited to a taught Masters programme before they progress to 3 years of PG research. This is made possible (and attractive) by our substantive taught Masters programmes offering a wide choice of specialism.

	13/14	14/15	15/16	16/17	17/18	18/19	19/20	Average
Total	48	60	63	60	61	62	74	61
UK	48%	47%	40%	40%	34%	35%	30%	39%
Europe	10%	22%	24%	25%	34%	31%	28%	25%
Overseas	42%	32%	37%	35%	31%	34%	42%	36%
Male	58%	58%	59%	53%	56%	55%	64%	57%
Female	40%	40%	41%	47%	44%	45%	36%	42%
Unknown	2%	2%	0%	0%	0%	0%	0%	1%

Table 4. Diversity of our PGR student cohort

As part of our strategy to increase student diversity we have engaged with the **African Institute for Mathematical Sciences** (AIMS), a pan-African network of centres of excellence: we are one of the first Units at a UK HEI holding a Memorandum of Understanding enabling a staff exchange between Glasgow and AIMS centres. Several of our staff members (Athorne, Chanialidis, Cobbold, Krähmer, Low) have taught advanced courses in Africa and our two EPSRC GCRF awards also support our engagement more generally in Africa and India. The MoU and awards have allowed us to support and recruit PhD students funded by the Schlumberger Foundation as well as remote supervision of PhD students in Africa to grow PhD capacity. In addition, 2 students are currently supported through the Graduate Assistantships in Developing Countries initiative (Makerere University, Uganda).

The proportion of female students registered for our postgraduate research degrees is on average 42%, twice the 2017 National Benchmark[2] of 26%. We believe this is a direct result of our Unit's diversity activities (detailed below) and our above UK average of 29% female professors serving as role models.

Recruitment, support and training mechanisms for PhD students

We have a PGR Team of 3 staff members, and it is Unit policy to appoint at least one female member to the PGR Team to support gender diversity within our PGR cohort. Together they oversee the recruitment process and manage support mechanisms and training provision. The head of the PGR Team is a member of the Unit's Research and School Management Committees. The team assesses the suitability of applicants, organises applicant visits and supports joint supervision and collaboration. Offers are discussed in a committee of senior academics to balance supervision load, monitor equality and diversity and widening participation. When assigning doctoral scholarships, we prioritise ECRs and pair them with experienced supervisors to support their development of supervisor skills. Induction is delivered through a dedicated member of our School Office who remains the main contact for administrative matters and the PGR Team who look after academic issues and monitor progress. We hold regular town-hall style meetings with the students to discuss any concerns and the PGR community elects 2 representatives who relay any concerns to the PGR Team.

To support the academic and skill development of our students we provide substantial funding for all 1st year students to attend postgraduate level courses such as the Academy for PhD training in Statistics (APTS) and the Scottish Mathematical Sciences Training Centre (SMSTC) broadening the mathematical sciences background of graduate students across Scotland and supporting our widening participation strategy. Our staff is actively engaged in SMSTC course development and delivery as well as providing stream leaders of subject areas (Cobbold, Gratz).

Our Unit offers financial support to PhD students to attend summer schools, workshops and conferences (Table 2) allowing them to build up their own personal networks, acquire new skills and disseminate their work. Examples include the Research Student Conference in Statistics, LMS workshops and the British Mathematics/British Applied Mathematics Colloquium. Applications for international travel scholarships are supported, and typically 1-2 students per year spend a period of study overseas. Every year we also welcome a small number of overseas students for short visits (1-2 per year).

Monitoring, progression and support

There is a robust annual review process for progression and development: each student gives an oral presentation, and submits a written report followed by a mini-viva with two members of staff not involved in their supervision. This process is used to identify and offer support to students who might be struggling as well as providing a forward looking discussion and development opportunities for those making good progress. This has ensured the timely completion of PhD theses, see Table 3.

Success Highlights

Evidence for the effectiveness of our support mechanisms is the success of our students, for

example SofTMech PhD students Mason (supervised by Ogden, 2019) and Paun (supervised by Husmeier, 2020) were awarded the Gold Medal at the prestigious STEM for Britain event held in UK Parliament. Currie (CASE and Industry PhD student) won best poster prize (supervised by Scott and Miller) at the 2019 RSS Conference, and Paun (supervised by Husmeier) won the Best Student Paper award at ICSTA 2019.

One inspiring story is the science engagement of Dr Angela Tabiri (supervisors Brown and Krähmer) funded by the Schlumberger foundation and identified through our engagement with AIMS. Angela represented our School at the international Science Slam in Prague. Her presentation on "Noncommutativity in the world and in mathematics" subsequently gained big audiences on social media and she went on to build on this success when organising the first ever **Science Slam Ghana under the auspices of *Femafricmaths***, a non-governmental organisation in Ghana involved in the promotion of science and women in mathematics, where Angela takes a lead role (she is now an AIMS-Google fellow).

2.3 Equality & Diversity

Two of our priorities are to ensure that we not only offer support for all our staff taking into account different personal circumstances through a number of policies (study leave, flexible working arrangements etc. described below) but also that we promote the inclusion of all underrepresented groups in the mathematical sciences. We currently have 27% female research only staff (2017 UK National Benchmarking Study: 21%[2]), 29% female professorial staff (2017 UK National Benchmarking Study: 11%[2]) and our unit management committee is 50:50. Over the REF period we have also increased the diversity with respect to nationality among our staff (see Figure 3).

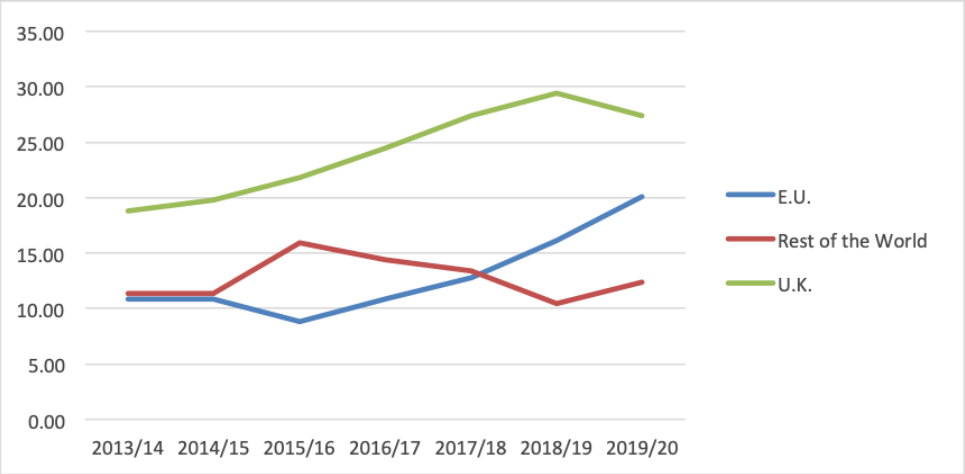

Figure 3. Nationality groupings of our R&T staff

Promotion of diversity

The School has a long-standing culture and tradition of tackling the lack of diversity. We have already detailed our involvement with AIMS and in EPSRC GCRF awards to address diversity in ethnicity (currently 17.5% of our staff are BAME and 76.2% White). Our Unit has also made leading contributions to equality practices whose efficacy has been recognised nationally and internationally.

Owens' "Too Long Long-List" approach to achieve **diversity at conferences** while serving as lead organiser for the British Topology Meeting at the University of Glasgow in 2016 has informed our seminar speaker selection process with the aim of increasing the percentage of underrepresented groups. The effectiveness of this approach is evidenced by a progressive increase from 12.5% to 23.5% of female speakers in our research seminars. This policy success was brought to the attention of the London Mathematical Society, which adopted it in their document "Advice on Diversity at Conferences and Seminars" in 2018. Since then the LMS has been approached by the Mathematical Societies of New Zealand and of Brazil who expressed a wish of adopting it as well.

Women are represented at the top managerial and subject specific level of our unit: our Heads of Subjects in Mathematics (Brendle) and Statistics (Miller) are female professors as is our School's Research Director Scott. The REF submission was jointly delivered by two senior staff (one female) while the output selection team (comprising 8 staff) included 3 women.

Several of our staff members have been recognized in their roles to raise awareness to equality and diversity issues. Lecuona is EMS representative on the LMS Women in Mathematics Committee. Gratz was a workshop leader for the second WINART (Women in Noncommutative Algebra and Representation Theory) meeting in 2019. This entails leading a research group of five female early career researchers in a joint research collaboration. Neocleous won a Suffrage Science Award in 2018 and Brendle has been recognized for both her contributions to topology and geometry as well as for her "service to the profession aimed at the full participation of women in mathematics" through election as Fellow of the American Mathematical Society in 2019.

Equality and diversity policies

In order to consolidate our success in recruiting a higher than average percentage of female staff and PhD students the School has formed a **Self-Assessment-Team** (SAT) in 2016 preparing for an Athena Swan Bronze Award, chaired by the Head of School. Some main points on the SAT agenda have been to look at simplifying the application procedure for positions across all subject categories within our Unit and, particularly, increasing the number of female staff shortlisted for academic positions. Our staff have undergone training regarding equality and diversity (92%) which informs staff roles in their day-to-day teaching and supervision roles as well as membership on interview panels and committees.

The SAT has also taken concrete steps in improving the experience of and facilitating support for staff taking career breaks due to personal circumstances by issuing unit specific and detailed guidance documents for flexible working arrangements and managing career breaks. Our new **Parental Leave Guidance** highlights Keeping-in-Touch (KIT) days (and SPLIT days for Shared Parental Leavers) to help staff keep up with any developments, attend training days and other events. Returners from maternity/paternity/adoption/shared parental leave can apply to a College **Academic Returners Research Support Scheme** for funding (up to £10k), to support resumption of their research on return. Funding can be used to buy-out teaching time, provide administrative or research assistance, fund pilot work for a grant application or travel to conferences etc. 3 staff have benefitted from these schemes over the REF period.

Our Unit has an **Engagement Lead** (Brendle) whose role is to facilitate constructive dialogue between School members with university and school management and we have developed a staff survey (2019) to identify areas where changes can be made. A concrete outcome has been a change in our IT policy: we now provide laptops as well as desktops to staff with caring responsibilities to facilitate flexible working hours.

The Unit has a dedicated **Disability Coordinator** (Jackson) who monitors that the needs of disabled students and staff are met and who liaises with the University's disability services if support cannot be provided at Unit level. Several awareness workshops have been organised in our Unit highlighting issues and needs of students with mental health issues and disabilities. Key figures in our support, administrative and academic staff have been trained in mental health first aid. We are currently in the process of widening participation to other staff in key teaching and support roles.

3. Income, infrastructure and facilities

3.1 Current research income & supporting strategies

Since REF2014, the university has made significant investments in the Unit via a new building, more than 20 new staff (4 in senior leadership positions), as well as promotion of staff (6 to professor within the REF period) and increased funding for PhD studentships. As a result, our research awards have effectively tripled across the Unit and staff career stages, rising from £1.2M in 2014 to a

sustained level of more than £4.3M in 2019/20 (Table 5) with a grand total over the REF period exceeding £17M. Our research income has almost doubled from £885K in 13/14 to £1.6M in 19/20, with total income of £9.3M. This is remarkable given the 32% of ECRs within the Unit. Our research funding comes from a wide variety of sources reflecting our breadth of research in the Mathematical Sciences, interdisciplinarity and also our outstanding and diverse collaborative links (see Section 4). Funders include EPSRC, EU, MRC, NERC, BBSRC, ESRC, Royal Society of Edinburgh, the Nuffield and McDonnell Foundations, the Wellcome, Biometrika, Carnegie and Leverhulme Trusts, in addition to industrial funding (such as Glaxo Smith Kline and Devro (Scotland)) and University and College research support funds for PhD studentships, impact and knowledge exchange grants. We have been successful in gaining a wide variety of smaller grants (including from RSE, RS, LMS), which are invaluable in supporting staff visits, visitors and conferences and from agencies (SEPA, PHS) to run training courses for their staff. A breakdown is shown in Table 5 below.

Sum of Proportioned Award Value	13/14	19/20	Grand Total
BIS Research Councils	£876,631	£3,132,361	£12,557,788
EU Charities and Other Sources	£11,563	-	£84,699
EU Government Bodies	£77,000	£979,260	£2,267,955
Industry (all sources)	£24,750	-	£376,483
Overseas	£3,016	£27,261	£320,581
UK Charities	£239,522	£70,699	£1,271,275
UK Government	-£836	£50,941	£125,890
UK Other Sources	-	£1,100	£30,010
Grand Total	£1,231,646	£4,261,622	£17,034,681

Table 5. Research awards

Our staff actively pursue prestigious fellowships and major awards. Across the Unit, 13 competitive fellowship awards have been won (Table 6).

Fellowship Funder/Scheme	Staff member	Dates	Current Position
Leverhulme Fellowship	Hill	2020-2022	Professor
RSE Fellowship	Husmeier	2019	Professor
ESPRC Advanced Fellowship	Luo	2019-2024	Professor
Feodor Lynen Fellowship	Bönicke	2019-2021	Rankin-Sneddon Fellow
Royal Society URF	Davison	2018-2023	Professor (Edinburgh)
Leverhulme Fellowship	Cobbold	2018-2020	Professor
EPSRC Postdoctoral Fellowship	Raedschelders	2018-2021	Research Fellow (Belgium)
EPSRC Early Career Fellowship	Bartel	2017-2022	Professor
Biometrika Fellowship	Macdonald	2016-2018	Lecturer
Humboldt Fellowship	White	2015-2018	Professor (Oxford)
Leverhulme Emeritus Fellowship	Brown	2018-2021	Professor
Leverhulme Fellowship	Luo	2015-2017	Professor
EPSRC Early Career Fellowship	Wemyss	2013-2021	Professor

Table 6. Fellowships

In **Applied Mathematics and Statistics,** the Unit has been consistently successful in winning significant research funding in “Mathematical sciences applied to healthcare technology” and is now a leading UK and global centre for soft tissue modelling. These awards include SofTMech, an EPSRC investment in soft tissue modelling led by Hill, Luo and Odgen and supplemented by the

award creating the Centre for Multiscale soft tissue mechanics with MIT and POLIMI led by Hill and the recently awarded Hub for Statistical Emulation (Husmeier) which will translate our research into clinically applicable tools (more than £5M awarded). These major awards have also been instrumental in leveraging significant additional research funds from industrial partners and charities including Glaxo Smith Kline, Devro (Scotland), and the BHF.

In **Pure Mathematics**, the unit has seen considerable success with the £3.3m EPSRC Programme Grant in Algebra in 2019 (Wemyss CoI, joint with Edinburgh and Sheffield), an ERC consolidator award of €1.3M in 2020 (Li) and an ERC starting grant of €1.2M in 2018 (Davison, now professor at Edinburgh University), further evidencing the standing of our Unit as a major UK and international research centre across subject areas.

In **Statistics and Data science**, with a focus on Environmental Statistics, our Unit led the quantitative modelling programme (Miller, Scott and O'Donnell) in GloboLakes, a NERC £5M consortium project and Hydroscape, a NERC £3.7M project (Miller and Scott). Scott led the £1.4M EPSRC funded WEFWEBs (modelling the water energy food nexus) consortium project with 7 academic partners and the EPSRC network plus SECURE, which built a network of statisticians, modellers and environmental scientists from more than 15 partner organisations. In Environmental Epidemiology, Lee has won awards from both EPSRC and MRC researching long-term health effects of air pollution and developing Bayesian spatio-temporal models for cluster detection, in disease risk.

We have seen success in awards including the EPSRC centre "Exploiting closed loop aspects in computationally and data intensive analytics" and "Computational inference for systems biology" (Husmeier EPSRC). The Unit also plays substantial roles in major cross-disciplinary research investments. These include the Quantum Technology Hub in Quantum Enhanced Imaging, one of four quantum technology hubs that are part of the UK Government's £270m National Quantum Technology Programme (Bowman and Evers). The unit was a founding member of the £7M Urban Big Data Centre (Scott, Dean and Bowman), one of 4 ESRC investments in data centres and in the ESRC Applied Quantitative Methods Network (AQMEN) (Dean, Lee, Bowman).

Distinguishing features of our research strategy are our procedures and support mechanisms to stimulate exchanges with industry, public and third sector bodies. A large number of our awards include strong partnerships across environmental, and health sectors as examples. We have made a number of honorary appointments (see Section 4 for further details) and also frequently deliver training courses and workshops with external attendees.

3.2 Support Mechanisms

We have a research support system that operates both at a local unit level underpinned by university wide support.

Unit level. Research is facilitated by the Research Committee, chaired by a senior professor (Scott), which coordinates and publicises funding initiatives, liaises with College/University wide support and provides discipline specific guidance and peer review. For applications to funding schemes that include an interview, our Unit provides full mock interview panels. The Head of School Administration offers advice and support to staff in preparing their financial applications.

College & University Level. A variety of support mechanisms are provided across the University and College and through bespoke funding schemes. The College Research Support Office provides local support to Principal Investigators from the proposal stage through to final reporting, ensuring high-quality submissions and effective management of awards. Two dedicated members of staff from the College Support Team are based part time within the School to assist in the application for and administration of grants. The College Research and Business Development Managers help research staff identify funding opportunities, develop proposals and support external engagement with a view to creating impact. Our staff has also benefited from several College and University wide funding schemes that support PhD, PDRA and staff mobility, and from a number of University initiatives including the Lord Kelvin Adam Smith (LKAS) scheme which aims to attract and retain

outstanding researchers (LKAS fellows). The School hosted one such fellow (Kosta). The LKAS PhD studentship scheme supports interdisciplinary research and the unit has had a number of successes in these competitions. We have won 5 such studentships over 7 years (20% of those awarded to the College of Science and Engineering). Staff within our Unit have benefitted from the EPSRC Impact Acceleration IAA funds (Miller, Scott, Bowman, Luo and Neocleous), the Glasgow Knowledge Exchange Fund (GKE) (Scott, Bowman, Luo) and the Glasgow GCRF Small Grants Fund (Miller and Scott, Ray, Bowman) to further our impactful research.

3.3 Infrastructure & Facilities

One significant change since REF2014 has been the £10M University investment in a new bespoke building (completed in 2017). Our building was planned and designed with the direct input of the Unit's academic and support staff, resulting in a building with a highly flexible layout to facilitate scientific meetings and collaborative exchange, a dedicated staff space for informal discussions and research seminars, generous office space for international visitors and a dedicated floor for our research students. The building has been a key asset in recruiting new staff members and PhD students. The building has also been instrumental in supporting and enhancing our vibrant and diverse research culture ensuring that we can bring together teams of individuals to work on collaborative research in both formal and informal settings. This investment is part of a major estate and infrastructure campus development plan and we are now centrally located close to the Advanced Research Centre opening in 2022 and representing a £113M investment which will host 600 academics, PDRAs and PGRs to stimulate interdisciplinary research.

At the same time, the Unit has heavily invested in its computing infrastructure to ensure that staff have resources needed in computationally challenging research areas. The new building has full 802.11 ac Wi-Fi network coverage and connects to the campus network via 2 x 10Gb connections. We have dedicated research computing facilities, comprising 33 high-specification servers offering 1000+ processing cores and combined 1.2Tb of RAM, and a Compute Grid, which offers 290 processing cores and 0.5Tb of RAM. The Unit has 4 IT support staff in total, managing the research computing environment and a dedicated IT budget of approx. £100K p.a. (see Table 2). We have invested in dedicated local IT support (4FTE) to manage and develop our research computing cluster and associated software.

Our **library provision** is of outstandingly high quality, enhanced by the many exchange agreements with the Glasgow Mathematical Journal. Library spending in the mathematical sciences is in excess of £126k per annum.

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

The Unit's breadth and depth in Mathematical sciences ensures that we are well placed to support and grow current interdisciplinary applications but also expand into new areas. Key to this vision are our national and international networks which overlap with and extend our more formal collaborative partnerships. Our Unit encourages, supports and strengthens new and existing collaborations through infrastructure (new building) and financial support (annual funds for inviting visitors and collaborators, conference travel), and ultimately research culture. We have appointed key collaborators to honorary or senior honorary research fellows or honorary professorships, thus ensuring that our staff and students are engaged with leaders in industry and government supporting our KE and inter-disciplinarity strategies. Many of our staff serve on external committees or working groups (e.g. the Scottish Government working group on creation of a low emission zone in Glasgow, Maths Counts, COMEAP (UK advisory Committee medical effects of air pollution), the Joint Nature Conservation Committee (UK advisory committee) and EU Science Committee (SCHEER)) as well as membership of learned societies). Staff and students have successfully participated for instance in the parliamentary event STEM for Britain, winning a number of awards.

4.1 Research collaborations, networks and partnerships

The Unit has a strong network of partnerships and collaborations (see examples in box below). Our networks are key in supporting major cross-disciplinary research projects and delivering impact (our

impact case studies include partners such as Shell, SEPA, PHS, EA, Newmetrica). These research connections have been developed through staff leading and participating in outreach and KE events and workshops, as well as advisory committee membership. Our unit has strategically driven the formation of academic and non-academic partnerships by supporting financially (Table 2) and in kind, a diverse range of activities including hosting visitors, supporting our staff to participate and organise research workshops, by co-funding PhD students and encouraging staff to co-author papers and reports. Academic collaborations and partnerships are fundamental for the delivery of our major grants, and in supporting our thriving research culture. We also are key partners in the delivery of collaborative PGR training (SMSTC, APTS see Section 2). We describe some highlights below.

SofTMech: supporting all aspects of SofTMech activities is a network of more than 18 international academic partners (led by Hill, Luo, Odgen). This is also supported by the SoftMech Centre to Centre success partnering with POLIMI and MIT. As part of the network there are frequent meetings with clinicians as well as representatives of health boards and drug companies to inform new treatment development and clinical trials.
EPSRC Programme Grant in Algebra and Geometry: the programme grant "Enhancing Representation Theory, Noncommutative Algebra And Geometry Through Moduli, Stability And Deformations" (CoI Wemyss) forms a partnership with 12 other universities and research institutes from Canada, France, Japan, the UK and the US supporting exchange visits and joint training of postdocs and PGR students.
WEFWEBs: led by the Unit (Scott), this was an EPSRC mathematical sciences led multi-disciplinary project modelling the water-energy-food nexus involving 7 other UK institutions. Policy briefs developed as part of WEFWEbs highlighted the importance of data in managing water-energy-food systems,
Globolakes: this NERC funded highlight grant has 5 academic partners and a non-academic partnership group. Research led by the Globolakes consortium has resulted in a Nature Climate change publication showing the impacts of climate change on global lake quality (based on novel statistical clustering methods developed by O'Donnell, Miller and Scott).
Hydroscape: this NERC consortium award includes 5 national partners,including the Natural History Museum, and British Trust for Ornithology. Miller and Scott with PDRA Wilkie have developed statistical models linking national biodiversity records to environmental quality to support conservation management decisions

Our Unit has also been a partner in EU International Training Networks and COST programme bids, e.g. the STARS ITN (focused on statistical and data sciences) bid included NTU, Norway, University of Vienna, University of Bologna. The successful Aquasense ITN led by UofG Engineering, in which we are a partner, includes 10 EU institutions in Poland, Sweden, Austria, Serbia and Italy as well as Exeter and Edinburgh Universities.

The Glasgow Mathematical Journal Trust (GMJT), through its funding schemes, invests in and facilitates many mathematical activities throughout Scotland from school level through to research level mathematics via some of the networks below dispensing approx. £45K per year.

We have been founders and members of a number of networks including Algebra and Representation Theory in the North (ARTIN), an LMS and GMJT funded network, Centre for Mathematics Applied to the Life Sciences (CMALS), Classical and Quantum Integrability (CQIS) a mathematical physics network supported by LMS Scheme 3 grants, GLEN, a LMS funded seminar network in algebraic geometry, The Scottish Topology Seminar funded by the GMJT, the Scottish Operator Algebra Research (SOAR) seminar funded by the EMS and GMJT, Statistical Methods for Atmospheric and Oceanic Sciences based in North America (STATMOS) and EPSRC funded network for Statistical Research in Environmental Sciences (SECURE). The activities of these networks range from organising research seminars, hosting and supporting visits, supporting pilot projects and running workshops. These networks and associated events ensure that the Unit's staff are well connected and aware of new research opportunities.

4.2 Research End Users, building bridges

We are acutely aware of the wider role mathematical sciences have to play in creating new technologies, contributing to the solution of environmental problems, health issues and other societal challenges. Our underpinning theme of cross-disciplinary research driving impact, has meant that we have invested effort in building a network of partners from industry and business, in government and non-governmental organisations and agencies. These partners have been instrumental as impact partners but also in developing our research and teaching agenda and in supporting bids for research funds.

Stimulating exchanges with industry, public and third sector bodies

To further advance our knowledge exchange and impact agenda, our Unit has appointed two industrial advisory boards since REF2014. These boards meet face-to-face annually but liaise more frequently via email and teleconferencing providing strategic input to research directions and new developments (members include representatives from the banking, pharmaceutical, official statistics sectors as well as industry). We have in addition appointed a number of honorary research fellows who are based in key partner organisations including Gemmell (former CEO Scottish Environment Protection Agency), Smith (Centre for Ecology and Hydrology), Heald (National Health Service), Trovato (Lloyds), Tough (RES industry). The boards and honorary appointments facilitate the development of impact pipelines. We have made our first inward secondment of Maier from Biomathematics and Informatics, Scotland (BioSS) and we have CASE PhD students with SEPA, Shell and Canon Imaging. Staff are also encouraged to take on external and honorary appointments (e.g. Lee with Committee on Medical Effects of Air Pollution (COMEAP) and Public Health Scotland, Scott with Joint Nature Conservation Committee).

Our major research grants (see Section 3) have included non-academic project partners. For illustration, SofTMech partners include the Golden Jubilee national Hospital, the M. D. Anderson Cancer Centre, the Ninewells Hospital and Medical School, the Greater Glasgow and Clyde Health Board, the Glasgow Clinical Research Facility, Ansys Inc, Clyde Biosciences Ltd, Dassault Systems Simulia Corp, Fios Genomics, LGC Ltd, Siemens Medviso AB, Mosaiques Diagnostics AG and Glaxo Smith Kline. Our air pollution and health research partners include Health Protection Scotland, NHS ISD, the Scottish government, Transport Scotland and Glasgow City Council. Our Unit's environmental and ecological research has benefitted from engagement with the environment agencies of Scotland and England, the Centre for Ecology and Hydrology and Plymouth marine Lab as examples. Recent CDT bids included more than 40 industrial and agency partners promising in-kind and financial support. Our Unit has benefitted from co-sponsorship of PhD students, CASE studentships, equipment and the provision of data.

We have delivered training workshops with and for our partners supported by training grants from NERC, LMS and others. For illustration, the EPSRC-SECURE network ran a series of workshops and training events open to partners and members and generated 15 collaborative pilot projects. SofTMech hosts regular industry workshops, and meetings with stakeholders including clinicians and patients. We regularly organize workshops and training courses for external organisations, linked to our open source software, for example, bespoke training courses funded by NERC and SAGES (Scottish Alliance for Geography and Earth Sciences) for the environmental sciences communities and for external organisations including SEPA, PHS and Dounreay.

4.3 Impact and outreach activities

Other major activities in our unit include outreach events for the wider public and pupils to promote the importance of STEM subjects and the important role mathematics has to play. These activities are coordinated by the Unit's Outreach Committee involving a cross section of senior academics, ECRs and PhD students.

In particular, our Unit is heavily involved in raising the wider public's awareness of mathematics through Brendle as member of Making Maths Count, a Scottish government profile-raising group, where she serves as part of the steering group for Maths Week Scotland. As part of Maths Week Scotland, which began in 2017, we have annually hosted a public lecture (2017: a statistics lecture by Heather Reid, 2018: a public EMS lecture by Mark Chaplain, 2019 and 2020: LMS Popular

Lectures by Holly Krieger and Diana Davis respectively). The "Maths Inside" photography competition (Wilson) is now in its 3rd year with over 500 entries in 2020 (commended by the Deputy First Minister of the Scottish Government).

A former staff member, Liberty Vittert (now Harvard University), developed outreach at national level through regular invited appearances on radio and television in Scotland achieving particular prominence with a TEDx talk to 2000 people in Glasgow. Her work raised the profile of statistical literacy in a variety of different fora, leading to her appointment to the BBC Expert Women Panel in 2018.

We run a series of Royal Institute Master classes (S3 pupils), University Taster Sessions (S5-6 pupils) as well as Open Days and our staff also participate regularly in the Glasgow Science Festival. Our Unit also runs the Ambassador Programme allowing some final year students to complete their BSc project in a local school working alongside teachers. This programme is hugely popular with both our students and the local schools, and has helped to root our Unit in the local community while inspiring the next generation of mathematical science students. Several of the participating schools are in deprived areas of Glasgow and this programme is supporting our widening participation ambitions. Table 7 gives an overview of our many activities.

Event	Date	Target Audience	Funding
Multiple SofTMech Training, Outreach and Engagement Events	2017-20	Clinicians, Industry, Patients, …	ESPRC
European Researchers Night	2017	General public	EU
London Mathematical Society Popular Lecture for Maths Week Scotland	2019	General public	LMS
LMS Undergraduate Summer School	2018	Mathematics UG students	LMS
LMS Popular and Edinburgh Mathematical Society Public Lecture for Maths Week Scotland	2018-19	General public	LMS/EMS
CISM (International Centre for Mechanical Sciences) Summer School: "Advanced topics in MHD"	2018	Postgraduate students	
Spatial health modelling training for analysts in NHS Scotland	2017	Clinicians and epidemiologists	School
NERC funded postgraduate training course in Environmental Statistics	2014-16	Environmental science PhD students	NERC
Exhibitions at Glasgow Science Festival	2015-16	General public	RSS and school
Anglo-Franco-German Representation Theory Network Summer School	2015	Academics	EPSRC
Bowman Lecture	2019-	Public and academic community	Endowment
Mitchell Lecture	2014-	Public and academic community	Endowment
Distinguished Lecture Series	ongoing	Wider community	School funds
Royal Institution Masterclasses	ongoing	S3 pupils	School funds
University Taster Days	ongoing	S5/6 pupils	School funds
Ambassador in Mathematics Scheme	ongoing	Schoolchildren and teachers	School funds

Table 7. Examples of Training, Outreach & Impact Events

The Unit has invested to create several distinguished lecture series representing the research areas within the school.

We host the **Mitchell and Bowman Lectures in Statistics** (from School endowments) as well as School funded **Rankin/Sneddon distinguished Lectures covering Pure and Applied Mathematics**. The Mitchell series was endowed in the 1930s, but the Bowman endowment was made only in 2018, while the Rankin and Sneddon series began in 2014. Our speakers under all schemes since 2017 have included Muffy Calder (Glasgow), Michael Wemyss (Glasgow), Vaughan Jones (Auckland), Elizabeth Thompson (Washington), Mike Cates (DAMTP), Peter Boyle (Lyon), Brendan Murphy (UCD), Philip Maini (Oxford), Yuji Kodama (Ohio State), David Spiegelhalter (Cambridge) and Chris Wikle (Missouri).

4.4 Contributions to the wider mathematical sciences community

Reflecting our commitment to the mathematical science community, our staff are actively engaged through editorial roles, service in learned societies, strategic committees of grant funding bodies and, more generally, provision of science advice (informed by the mathematical sciences); some key highlights are given below.

Staff in our Unit have been reviewers for and members on national (EPSRC, NERC, British Council, Carnegie) as well as international grant advisory boards: EU Commission (Marie Curie Fellowships and Science Council Scheer), DFG (Germany), FWO (Flanders), INRA (France), NWO (Netherlands), NSERC (Canada), NSF (USA), Vetenkapsradet (Sweden). Our staff has been heavily engaged in learned societies including 43 editorial memberships, 15 international grant advisory boards, 10 members of the Peer Review Colleges for EPSRC and NERC and 3 presidents of learned societies. Two of our staff members (Brown – chair for 3 years, Strachan) have served on the EPSRC SAT and another two are panel members for REF2021 (Brendle, Wemyss).

Our unit is also represented at the highest level of the national learned societies, Scott was International VP of the Royal Society Edinburgh (2016-2019), Strachan was President of the Edinburgh Mathematical Society (2015-2017) and Brown (2009-17) was VP of the London Mathematical Society. Brown was awarded a CBE in 2019 and the IMA-LMS Crighton Medal. Brown and Brendle were elected Fellows of the American Mathematical Society in 2019.

Brendle was LMS Council Member at large (6 years), and Lecuona is the EMS representative on the LMS Women in Mathematics Committee (a role she took over from Brendle in 2019). Whittaker is Convener of the EMS Research Support Fund Committee and Wilson is Convener of the EMS Education Committee. Scott is a member of Scottish Science Advisory Council, JNCC committee member, and serves on the EU Science Committee SCHEER. Lee has been appointed to COMEAP (2020-present).

Borisova, O'Donnell, Miller and Anderson have or are currently serving on Royal Statistical Society local group while Miller serves on the RSS Council and is a member of their academic affairs advisory group, and Lee was Honorary Secretary of the RSS environmental statistics section. Scott serves on the RSS Honours committee. Scott and Miller have both served on the International Environmetrics Society (TIES) board, Miller is currently secretary of TIES and in addition, she served two terms as secretary of the Statistical Modelling society (IWSM), Ray has been appointed to the board of the Newton Gateway and Scott is a member of the NERC advisory network, and the ICMS and INI management boards.

Our staff are encouraged and supported to actively engage in national and international conference organization, as well as chairing and serving on organizing and scientific committees for major discipline and cross-disciplinarity conferences (Table 8).

Conference	Date	Institute/Location
BMC/BAMC	2020	U of Glasgow – postponed to 2021
Mini-Symposium on Low-Dimensional Topology	2020	8th European Congress of Mathematics, Slovenia
GEOMED	2019	U of Glasgow
Tilting theory, Singularity Categories & Noncommutative Resolutions	2019	Banff Canada
Enumerative Arithmetic and the Cohen–Lenstra Heuristics	2019	MPIM Bonn, Germany
Low dimensional topology	2019	CIRM France
Symplectic Representation Theory	2019	CIRM France
RSS Conference	2018-19	Glasgow and Belfast
Royal Society Theo-Murphy meeting on Quantum Integrability and Quantum Schubert Calculus	2018	Int'l Kavli Centre of the Royal Society London
Joint Meeting EPSRC Centres for Mathematical Sciences in Healthcare	2018	U of Glasgow
Minisymposium "Multiscale Soft Tissue Modelling: Cardiac Electrophysiology and Active Contraction"	2018	British Applied Mathematics Colloquium St Andrews 2018
RSE-MOST Big Data Workshop	2017	Taiwan and Edinburgh
LMS/CMI Research School "Developments in Contact and Symplectic Topology"	2016	U of Glasgow
Frontiers in Functional Data Analysis	2015	Banff, Canada
International Environmetrics society conference	2016	Edinburgh
Operator Algebras: Dynamics and Interactions, Intensive Research Programme	2014	CRM Barcelona, Spain
Hamiltonian PDES, Frobenius manifolds and Deligne-Mumford moduli spaces	2013	SISSA, Italy

Table 8. Conference Highlights

4.5 Wider influence

Our staff regularly delivers invited conference presentations and plenary lectures in the UK and overseas. They are invited to visit recognized international centres of excellence such as the Institute for Advanced Study Princeton (Wand), the Fields Institute, Toronto (including Cobbold, Fortier-Bourque, Voigt), the Research Institute at Banff (including Brown, Cobbold, Illian, Ray), the CIRM Marseilles (Lecuona, Owens, Wand), the CRM Montreal (Korff, Valeri), the Max Planck and Hausdorff Institutes in Bonn (Korff, Lecuona, Owens, Voigt, Wand), the Mathematical Research Institute at Oberwolfach (including Brendle, Brown, Owens, Wand, White), the Bose Centre in India (Feigin) and the International Centre for Theoretical Physics (Torney) to name a few. Many of our staff are also regularly invited for extended research visits or visiting appointments at overseas institutes such the American Institute for Mathematics at San Jose (Cobbold), the IAS Princeton (Wand), the University of Chicago (Brendle), the NASA Ames Research Centre (Simitev), the Fields Institute (Cobbold), the University of Ottawa (Cobbold), the University of Melbourne (Korff), the University of Sydney (Bellamy), CSIRO (Scott).

In Mathematics Odgen delivered the Timoshenko Medal address at the ASME International Mechanical Engineering Congress in Phoenix, USA and the Hill Prize Lecture at the International Congress of Theoretical and Applied Mechanics in Montreal. Other noteworthy international plenary lectures associated with prizes which staff have won include the Barnett keynote lecture at RSS conference Belfast by Scott, the El-Sharaawi keynote delivered by Miller at the TIES conference in Guanajuato, Mexico, the lecture series given by Bowman in Australia and White's invited lectures at the European Congress of Mathematics and the 2015 Abel Symposium in Norway.

Our unit's international research profile and reputation is also demonstrated by 15 national honours, and international prizes (Table 9).

Prize/Award	Date	Name	Grade	Gender
Adam Prize	2020	Michael Wemyss	10	M
Fellow of the AMS	2019	Tara Brendle	10	F
Fellow of the AMS	2019	Kenneth Brown CBE	10	M
David Crighton Medal	2019	Kenneth Brown CBE	10	M
CBE	2019	Kenneth Brown CBE	10	M
Barnett Award of the Royal Statistical Society	2019	Marian Scott OBE	10	F
Dillwyn medal (STEM)	2019	Gwyn Bellamy	10	M
Abdel El-Shaarawi Young Research (AEYR) award	2018	Claire Miller	10	F
Suffrage Science Award for Mathematics and Computing	2018	Tereza Neocleous	8	F
LMS Whitehead Prize	2017	Michael Wemyss	10	M
Rodney Hill Prize	2016	Ray Odgen FRS	10	M
ASME Timoshenko Medal	2016	Ray Odgen FRS	10	M
Frank Hansford-Miller Award from the Statistical Society of Australia	2015	Adrian Bowman FRSE	10	M
Enlightener Prize for the best popular science book published in Russian in the natural and exact sciences category	2015	Mikhail Feigin (co-author)	9	M
Fellow RSE	2014	Xiaoyu Luo FRSE	10	F

Table 9. Prizes & Awards

In summary, since the 2014 REF, the Unit, has benefitted from significant university investments allowing, an upward trajectory in the strength, breadth and depth in Mathematical Sciences to become a major international research centre. We have appointed more than 20 (50% increase in FTE) researchers from across the globe to permanent academic posts, tripled our research funding, grown our PGR numbers by more than 50% and moved to a brand new £10M bespoke building. Our staff are globally recognised for their excellence, gaining numerous awards and holding senior positions in learned societies. Our breadth and depth in the mathematical sciences has enabled us to respond to a multitude of emerging research challenges including geometric theory, healthcare and the environment and to generate world-leading impact in environment, health and geosciences.