Institution: University of York

Unit of Assessment: 5 - Biological Sciences

1. Unit context and structure, research and impact strategy

Context and Structure of the Unit

Our strategy for Biological Sciences at York is to support impact-oriented, world-class interdisciplinary research that addresses three major **Global Challenges**: *Health and Disease*, *Sustainable Food and Fuel*, and *Environmental Change,* which align with three of the University of York's five research themes: *Health and Wellbeing, Environmental Sustainability and Resilience,* and *Technologies for the Future* (*see IES, paragraph 4*). **Figure 1** shows our strategy, where our impact-orientated research is supported by four **Multidisciplinary Research Centres**; York Biomedical Research Institute (YBRI, established 2018), Centre for Novel Agricultural Products (CNAP, established 1999), Leverhulme Centre for Anthropocene Biodiversity (LCAB, established 2019), and York Environmental Sustainability Institute (YESI, established 2011). These centres successfully underpin our drive to tackle global challenges by bringing together staff to collaborate at the interface of nine **Fundamental Science Research Foci (Figure 1).** Our research foci fall on a continuum, recognising our lack of boundaries between areas of research and also our inclusive environment that characterises Biological Sciences at York. Our researchers are buoyed by excellent **Underpinning Facilities and Support**, including workshop and technical staff as well as world-class equipment housed in the **Bioscience Technology Facility** (BTF), making new technologies accessible to all. We strive to create an environment where all our staff contribute to departmental objectives, growth, and impact, and we are proud of our inclusive culture which supports the wellbeing of all our staff.

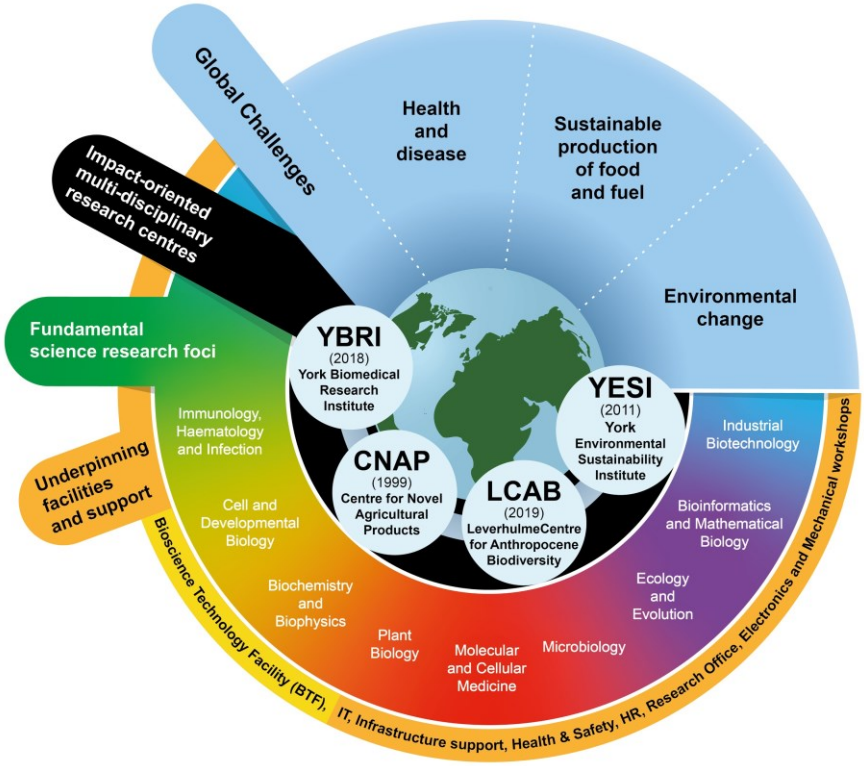

Fig 1. Schematic of Biological Sciences research structure at the University of York, addressing three global challenges.

Our research strategy has been successful and our research is flourishing; highlights during the REF2021 period include:

- Our new focus on Biomedical Sciences and setting up YBRI in 2018 has led to the doubling of our UG student community, and the associated growth and turnover of staff has resulted in the appointment of 25 new academic staff, strengthening our research across all career stages;
- Our vibrant interdisciplinary culture is strengthened by the formation of LCAB in 2019 (extending our collaborations to include the Faculty of Arts & Humanities), and the continuing success of YESI (>£25M of projects funded since its launch);
- We are proud that our supportive culture has resulted in a 58% increase in UKRI funding income, and our successful equality and diversity initiatives have been recognised by our Athena SWAN Gold award renewal in 2019.

The co-location of Departments and the campus layout of our University promotes interactions, and our multidisciplinary research centres help shape strategic decisions on new appointments. New staff appointments have been made jointly between Biological Sciences and the Departments of Maths, Computer Science, Physics and Psychology, and interdisciplinary research is fostered by research labs from the Hull-York Medical School (HYMS) and the Department of Chemistry's York Structural Biology Laboratory (YSBL) being co-located within the Biology Department (*see IES, paragraph 8*). We are proactive in supporting wider equality and inclusion; informal events such as LBGTQ+ seminars and Disability mixers provide safe spaces for everyone to socialise and exchange ideas. We are proud of our flexible and family-friendly working hours policy which supports a healthy work-life balance for all our staff. We believe that when all staff feel included, we work better as a whole.

An illustration of the strength of the energetic and interactive environment of York Biological Sciences is our swift and agile response to the COVID-19 emergency. We have pivoted to use our facilities and expertise in research collaborations and for public good, working with partners to support the COVID-19 response in our region. Led by the **Bioscience Technology Facility**, we were the first University to set-up and validate qPCR diagnostic tests (to support the NHS hospital in York). We relocated one of our qPCR systems, and our staff then supported testing for many months at York Hospitals. Our versatile and talented workshop staff provided the York area with personal protection equipment by 3D printing visors for frontline workers. Subsequently, our operations team managed the implementation of LFD-based testing technology on campus, for use by students, University staff, and the public. We instigated a partnership with the NHS to deliver rapid LAMP-based COVID-19 testing for NHS and other frontline staff in York, North and East Yorkshire, using laboratory facilities in Biological Sciences. York Biological Sciences (Kaye, Lagos, Signoret) is also a member of the UK Coronavirus Immunology Consortium, the largest single grant to be awarded by UKRI to study the role of the immune system to COVID-19, which will be critical to our ability to control the coronavirus pandemic.

Research and Impact Strategy

'*Biology without boundaries'* is the underlying ethos of our research and impact strategy, underpinned by the University's foundations of Research Excellence, Impact, Innovation, International Perspective, Collaboration and Partnership, and Integrity. York's success is built on a philosophy of individual, collaborative and interdisciplinary working enabled by an outstanding research environment. Our success in Biological Sciences is evidenced by our six impact case studies that are delivering outstanding research outputs with international benefits that come from collaborations within our multidisciplinary research centres (CNAP, YESI, LCAB and YBRI) to tackle the three global challenges we have identified (Figure 1). These six selected case studies have arisen from our impact strategy to deliver global impacts to benefit biodiversity under environment change (*Improving effectiveness of conservation areas in Africa, Resilient strategies for conservation under climate change*) and human health & disease (*Tackling malaria with fast-track plant breeding, Poppy research creates new cough suppressant supply chain, Bladder tissue*

research impacts Actos multidistrict litigation bellwether case and $2.4 billion product liability settlement), and providing more sustainable food & fuel (*Improving sustainable oil palm*).

Our *Research and Impact strategy* is continually developed by the Departmental Research Committee (DRC), with broad representation from our research centre directors, senior and ECR academic staff, including PDRAs, and our academic **Research Foci** leaders, and the director of postgraduate research. Additional input comes from our distinguished External Advisory Group. Our Departmental **Impact Champion** identifies areas of research with high impact potential and ensures sustainability of our impact and vision for the future.

Our strategic objectives are to foster a research environment, that:

- enables internationally-leading research to flourish;
- promotes research which is open, transparent, and reproducible;
- encourages staff members to enjoy a healthy work-life balance that supports individual excellence and well-being, collaboration, interdisciplinarity and innovation;
- translates fundamental research findings into impact with global significance;
- contributes to developing regional, UK and international strategic research priorities, and is responsive to new opportunities;
- trains the next-generation of world-class scientists.

2014-2020: Achievements

We achieved our strategic objectives from REF 2014, which were to:

1. Enhance our world-leading core strengths: this achievement is demonstrated by excellent, collaborative outputs and investment in new staff.

Excellent, collaborative outputs

Our **Research Foci** (Figure 1) have developed ambitious strategies for both research and impact, delivering world-leading research outputs:

Immunology, Haematology & Infection addresses science that underpins the diagnosis and treatment of diseases, including developing a novel therapeutic for neglected tropical diseases of the developing world (Mottram in *Nature Microbiology*) and population dynamics in haematopoietic stem cells (Kent in *Nature,* 2018; Hitchcock in *Science,* 2020).
Molecular & Cellular Medicine confronts today's global health challenges, including diseases of ageing, including bladder cancer (Southgate in *Science Translational Medicine,* 2014), and approaches for understanding developmental disorders such as Rett syndrome (Goffin in *Nature Medicine,* 2017).
Cell & Developmental Biology provides insight into cellular mechanisms regulating cell differentiation (Coverley in *Nature Communications,* 2019), and information to direct novel therapeutic strategies from stem cells (Genever in *Stem Cell Reports,* 2015).
Microbiology encompasses studies of macromolecules to biotechnological applications, including the elucidation of structures and mechanisms of a genome segregation system in Archaea (Barilla in *Science,* 2015) and the characterisation of gene expression in a Gene Transfer Agent (Fogg in *Nature Communications,* 2019).
Plant Biology uses model and crop plants to investigate environmental challenges, including studies of the genetic basis of plant tolerance to diseases (Harper, Bancroft in *Nature,* 2017) and the efficiency of carbon-fixation mechanisms (Mackinder in *Cell,* 2017).
Biochemistry & Biophysics research examines bacterial cell envelopes, the targets of many antibiotics (Baumann in *Nature Communications,* 2018), and the enzymes responsible for morphine synthesis in poppies (Graham in *Science,* 2015).
Ecology & Evolution explores the impacts of environmental change on biodiversity, including range expansion by species under climate change (Hill, Thomas C in *Nature Climate Change,* 2019) and human-wildlife conflicts in African savannas (Beale in *Science,* 2019).

Bioinformatics & Mathematical Biology applies quantitative methods to solve biological problems, such as modelling bacterial evolution and spatial dynamics (Van der Woude in *Current Biology,* 2019) and generating multi-scale models of the infectious landscape using detailed imaging and q-PCR (Kaye in *Nature Communications,* 2017).
Industrial Biotechnology delivers strategic research impacts, including the discovery of new enzymes for biomass processing (McQueen-Mason in *Nature Communications,* 2018) and phytoremediation of explosives pollution (Bruce in *Science,* 2015).

New staff

The development of a new degree programme in Biomedical Sciences and new Integrated Masters programmes, and several retirements since the last REF period has allowed us to make 25 new appointments (i.e. 35% turnover/expansion of staff over the REF period) at Chair (5), Lecturer (17) and Research Fellow (3). This has enabled us to strengthen our research structure by reshaping our Research Foci and inter-Departmental initiatives to ensure exciting collaborative opportunities (Table 1).

Table 1. New appointments at Chair (C), Reader (R), Lecturer (L) and Research Fellow (RF; proleptic and/or Independent Fellowship).

Research Foci	Appointment
Immunology, Haematology & Infection	Mottram (C), Boucher (L), Kourtzelis (L), Myburgh (L).
Cell & Developmental Biology	Bryant (C), MacDonald (RF)
Plant Biology	Denby (C) as Director of the N8 AgriFood Resilience Programme, Mackinder (L), Harper (L)
Molecular & Cellular Medicine	Rot (C), Kent (RF), Brackenbury (L), Goffin (L) , Chen (L), Hewitson (L), Holding (L)
Microbiology	Hawkins (L), Fogg (RF)
Ecology & Evolution	Thomas, M (C), Jeffares (L), Friman (L)
Bioinformatics & Mathematical Biology	Dykeman (L), Ezer (L)
Industrial Biotechnology	Tonon (L), Lichman (L)

2. Establish a strategic initiative in Biomedicine

To provide an internationally-competitive multidisciplinary research environment for fundamental and translational research in biomedical and clinical sciences we established the **York Biomedical Research Institute (YBRI)** in 2019. YBRI is a major initiative with 85 academic staff working across disciplines, with three research themes that address key questions in Immunology, Haematology & Infection, Molecular & Cellular Medicine, and Neuroscience. The launching of YBRI has been associated with the appointment of 13 staff in Biological Sciences, including the YBRI director (Mottram). An example of an interdisciplinary project is Hitchcock and Kent's work on the molecular and cellular bases of haematological malignancies which, through YBRI, interfaces seamlessly with applied health epidemiological work in the Haematological Malignancy Research Network.

3. Strengthen and develop interdisciplinary research centres and institutes

To accelerate rates of discovery and translation of research into impacts, in addition to **YBRI**, the following research centres have been developed and/or strengthened:

Centre for Novel Agricultural Products (CNAP)

CNAP was established in 1998 as an interdisciplinary centre to harness the power of nature for the development of new products and processes to address some of the major global challenges of the 21st Century, generating impacts relevant to all three of our global challenges in Biological Sciences. CNAP supports large multi-investigator programmes that involve and benefit pharmaceutical (e.g. GSK), biofuel (e.g. Novozymes) and agricultural (e.g. Syngenta, BASF, East-West Seeds) companies. Over the REF period, CNAP has identified new research opportunities and built on existing projects in industrial biotechnology, which includes four BBSRC Networks in Industrial Biology (NIBB) awards (Lignocellulosic Biorefinery Network and Biomass Biorefinery Network, McQueen-Mason; High value Chemicals from Plants Network and High Value Biorenewables Network, Graham), maintained its track record of continuous funding during the REF period from the US Department of Defense (total to date = $5.4M) to tackle environmental pollution (Bruce) and from the Bill & Melinda Gates Foundation (total to date = $27M) to commercialise new varieties of the medicinal plant *Artemisia annua* (Graham). The **Biorenewables Development Centre** (BDC) is an open-access R&D centre working at the interface between academia and industry in partnership with CNAP. The BDC was set up in 2012 to develop, scale-up and help commercialise bio-based products and processes, and its continuing success resulted in it moving to new premises in 2015.

We have committed to the long-term future of CNAP by appointing ECR group leaders to build on and sustain its success in the translation of fundamental research into impact. Four new ECR appointments have been made (Mackinder, Tonon, Harper, Lichman), ensuring sustainability of our successful research centre. Mackinder was promoted to a personal Chair in 2020 and both Mackinder and Lichman have been awarded prestigious UKRI Future Leader Fellowships.

York Environmental Sustainability Institute (YESI)

YESI brings together social, physical and life scientists to deliver world-leading interdisciplinary research and stakeholder collaborations in environmental sustainability, to benefit industry, NGOs, advisory agencies and policy makers (e.g. Nestle, DLF Trifolium, Joseph Rowntree Trust, Design Council, ADAS, Natural England). YESI has over 100 York-based researchers associated with YESI projects. The new YESI Director (Thomas, M.) was appointed in 2020 following Prof Sue Hartley's appointment as PVC for Research at the University of Sheffield. Many YESI projects are co-designed with external partners who support the co-creation of knowledge and collaborations to deliver improved policies, new practical tools for businesses, farmers and consumers, and improved livelihoods. For example, the Socially and Environmentally Responsible Oil Palm Research (SEnSOR) project addresses the challenge of the sustainable cultivation of palm oil by testing the effectiveness of conservation management practices and helping to improve

certification criteria for sustainable palm oil certification. YESI has received £10M investment by the University that includes a new building for the Departments of Environment and Geography, Archaeology and Biology, as well as increased funding for new YESI staff to support coordinating research, grant bids and business development.

The Leverhulme Centre for Anthropocene Biodiversity (LCAB)

LCAB was established in 2019 as a highly interdisciplinary centre, funded by £10M of competitive funding from The Leverhulme Trust, with matching investment in researchers and infrastructure by the University of York (LCAB director is Prof Chris Thomas FRS). The 10-year programme is exploring how the relationship between humanity and the natural world is changing, and how to develop a more sustainable Earth. LCAB will employ 10 PDRAs per year and 24 PhD students in total, and involves collaborations across the sciences (Biology, Health Sciences, Environment & Geography), social science (Management School, Politics) and humanities (Archaeology, English, History, Philosophy), ensuring that policy impacts from our ecological research continue to expand as a major strength of our activities.

In addition to our Research Centres we have implemented boundary-crossing research initiatives:

N8 AgriFood Programme is a unique programme hosted by the University of York in the Department of Biology that is working across the food system. It combines expertise from the 8 most research intensive universities in the North of England, with the Principal Investigator (Professor Deborah Smith OBE, PVC for Research, 2015-20), Academic Director (Denby) and the Operations Director all based at York. The N8 AgriFood Programme has created a successful platform for collaboration and led to a transformation in the research culture in the N8 universities. The programme has delivered external funding to the N8 universities for large interdisciplinary projects, created new industrial and stakeholder partnerships, and elevated the international profile of agri-food research across all 8 institutions. The programme recently launched a Food Systems Policy Hub to help deliver social and environmental change required to tackle the urgent challenges the food system faces.

Key achievements of N8 Agrifood Programme include:

- £28M+ of external funding secured for projects arising from N8 AgriFood activity
- 29 Industry partners engaged in externally-funded projects
- Pump-priming of 147 multi-institution collaborative projects.

BioYork was launched in 2019 to translate cutting-edge research into technologies, processes and products across the bioeconomy. Driven by industrial demand and founded in excellent science, BioYork acts as a centre of gravity in the North of England to:

- Attract inward investment in new, bio-based businesses with high growth export markets
- Anchor knowledge-based jobs in sustainable manufacturing in the UK
- Help deliver the UK's commitments under the Climate Change Act

The director of BioYork (Graham) is based in the Biology Department, and refurbishment and redevelopment of space in the department has been provided to accommodate BioYork staff.

Strategic aims and Vision

Our future strategic goals for research and impact are to:

1. **Increase our capacity to address our global challenge-led research themes** by new recruitment (25 new academic research and teaching posts are planned over the next four years as we address our new research challenges post-COVID-19). This increased capacity will provide greater scope and ambition for us to deliver solutions for our challenge-led research themes. Sustainable Food & Fuel will be expanded to include

Sustainable Medicines & Materials, our Environmental Change theme will incorporate a distinct focus on the current threats to Biodiversity, and our Health & Disease theme will expand to include more focus on Planetary Health, enhanced support for Translation of Biomedical research and the establishment of a new York Skin Research Centre.

2. **Enhance our capability in computational methods and artificial intelligence applied to questions in the biological sciences.** Exploitation of potentially disruptive technologies requires substantial investment in data analysis tools and approaches. Emerging techniques such as single cell genomic and transcriptomic sequencing, global proteomics, and advanced time-lapse and super-resolution imaging as well as their analysis pipelines are now embedded in York as a result of key recent appointments (Table 1; Kent, Holding, Jeffares, Ezer) and strategic infrastructural purchases (e.g, SmartSeqII, TmT proteomics, 10X Chromium, high-end computing server). This underscores our commitment to transforming our capability in these areas as we expand our capacity to support new world-leading translational research in areas such as regenerative medicine and gene therapy.
3. **Enhance impact through our industrial collaborations and international collaborations.** We were awarded two of the six (and ~£5M of the available £11M funding) Phase II BBSRC Networks in Industrial Biotechnology and Bioenergy (NIBBs) in 2019, building on two previous Phase I NIBBs, demonstrating our strong commitment to industrial collaborations. Biological Sciences at York has been highly active in developing and winning bids for Official Development Assistance (ODA) funding e.g. MRC/FAPESP Joint Centre Partnership in Leishmaniasis (JCPiL; led by Mottram; £2.3M). We have received international funding from the Bill & Melinda Gates Foundation to develop higher-yielding varieties of the medicinal plant *Artemisia annua*, and from the US Department of Defense for research on phytoremediation of environmental pollutants. We will build on our excellent record, encouraging entrepreneurship and internationalism through provision of new opportunities for training and support for staff and (research and taught) students. Our Impact Champion will help increase the number of industrial and international collaborations, and the number of research staff involved in these activities.
4. **Be influential in, and responsive to, UKRI, InnovateUK, BEIS, EU and UN priorities and initiatives** for sectors relevant to the biological sciences including health, food, fuel and environmental sustainability, to ensure we continue to contribute to the UK's economic performance and social (including international) responsibilities through our areas of strength. We will encourage staff to take on significant strategic and leadership roles in funding bodies, charities, and government policy initiatives.
5. **Align PGR student recruitment and training with our priority research areas** through our interdisciplinary Doctoral Training Programmes e.g. BBSRC White Rose DTP, NERC ACCE DTP, our newly approved Biomedical Sciences PhD programme (to be launched in 2021), and LCAB studentships. We will continue to diversify our funding streams for doctoral programmes, building on new and existing industrial, charitable and international networks. We will build further provision at Masters level, developing interdisciplinary programmes with business, engineering, and social sciences which are aligned to our involvement in interdisciplinary research work in these areas, to enable even more effective realisation of impact from our biological sciences research.
6. **Strengthen the development of infrastructure to facilitate research.** An exciting phase of infrastructure provision has established new space for the new **Leverhulme Centre for Anthropocene Biodiversity (LCAB)** in a flagship location on the University campus. LCAB will explore the different scientific, social and cultural perspectives on the Anthropocene, during a time of biological gains as well as losses, and human benefits as well as harms. We will continue to support initiatives for establishing research and impact entities, acting in an agile way to relevant funding opportunities that align with our research themes, and helping these to flourish through capital expenditure on buildings, facilities and infrastructure.
7. **Upgrade our research facilities** to support our research priorities and industrial partners**.** The **Bioscience Technology Facility** will continue to be key in delivering this support as it provides a mechanism of professional equipment management that is well understood

and respected by funders and industrial partners, ensuring York staff have access to the most up-to-date technologies.

8. **Embed Open Research** as a central principle in policy and practice in our research processes. We will appoint an **Open Research Champion** to help drive new initiatives and liaise with the University.

Progressing towards an open research environment

Developing a research environment that promotes and facilitates open data and knowledge exchange to share ideas through collaboration is central to our aims. To ensure our research is widely available, well-managed, and searchable, we are setting out a framework to make this happen. We expect all staff to include a Data Management plan as part of their research programmes, using them as 'living documents' that include details on how data are safely stored and for how long, as well as how methods and protocols are shared with the scientific community so that data can be effectively used. We are making a specific investment in our PDRA/PGR community, taking a 'bottom up' approach by providing training in using and sharing data, thereby promoting the ethos that open research is reproducible research. Our training programme has been developed by a Software Sustainability Institute Fellow (Rand) and is influenced by the Mozilla Open Leaders programme and The Turing Way. This training enables and encourages researchers to conduct Open Research by equipping them with the data management and software development skills required to ensure the computational reproducibility of their work.

Open access and data management

We have taken a 'top down' approach by introducing robust open access and data management plans. The York Open Access fund provides funding for authors to cover payment of open access publication charges, as required by funders. All data published are submitted to the relevant data bank: Genomic and transcriptomic data made available through repositories such as NCBI, the Gene Expression Omnibus (GEO) or ArrayExpress, DNA sequences are submitted to ENA and Genbank, and 3D structures of proteins are submitted to PDB. Processed peptide data (contigs, data quality indicators, peptide mass fingerprint peak lists and MASCOT results) are shared via publication in journal supplementary information. Ecological and environmental data are uploaded to data repositories such as Dryad, and NERC Environmental Information Data Centre (EIDC), with R and model code available on GitHub. Metadata records are available via the University's Current Research Information System (PURE), as a permanent and public record.

Good management of research data is central to discovery and innovation, allowing data to be scrutinised and reused; the practices for open research that we are establishing in Biological Sciences will promote robust and reproducible science.

Supporting a culture of research integrity

We are committed to ensuring that research integrity is embedded in our science. To do this, we keep researchers well-informed about the University's ethical framework and ensure their compliance with current legal, regulatory, and institutional principles and expectations when planning, conducting, and disseminating their work. The University's Code of Practice on Research Integrity formally endorses the UUK Concordat to Support Research Integrity (*IES, paragraph 14*).

Rigour, transparency and accountability are key aspects of the University's Code of Practice for Research Integrity. This directs us to undertake an ethical review of projects as they are planned, to plan for impact and public engagement, and to publish in Open-access journals. We have established protocols in our research planning guidelines to identify and consider ethical issues in research projects before they begin. The University has a devolved model for the scrutiny of research proposals, which for Biological Science comprises an overarching University Ethics Committee as well as the Biology Ethics Committee (BEC), which provides guidance and support

to staff and research students during the development of their research methodology and also when applying for external ethical approvals.

In addition to relying on individuals to self-report, BEC also conducts an annual audit of our research, in which academic staff answer a series of questions about their research. This audit helps to identify any new projects which may require ethical review, and includes collaborative activities that may be taking place overseas or at another institution in the UK. This audit is also used to identify research which uses genetic resources in scope of the Nagoya Protocol, which is then subject to a University-wide process of due diligence in terms of record keeping and reporting. In addition, PGR students undertake an ethics training course within the first few months of their start date, and submit an ethical responsibilities form to BEC. Projects that have received ethical review via the NHS Research Ethics service, other UK higher education establishments or appropriately regulated overseas institutions or which are licensed by specialist bodies such as Natural England are eligible for expedited review by a sub-committee of the Biology Ethics Committee. Researchers using animals protected under UK Animals (Scientific Procedures) Act 1986 are reviewed by the University's Animal Welfare Ethical Review Body (AWERB; Biology chair) to support their application for Home Office approval of their research.

2. People

Staffing Strategy and Staff Development

We aim to attract, retain and develop a diverse research and professional support community and provide an environment that nurtures potential and promotes excellence at all career stages so that everyone is supported to contribute to our research goals.

Staffing in relation to our research and impact strategy

Since 2013, we have enjoyed a period of sustained expansion of our academic faculty, which we plan to continue. Our recruitment strategy ensures a sustainable mix of experienced leaders and early career researchers, with a focus on appointing lecturers (Table 1), and prioritising the appointment of those with potential to tackle fundamental scientific questions aligned to our research strategy and future impacts. To drive forward new initiatives in strategically important areas, we look to recruit academic leaders with the vision to meet new challenges, and we have appointed 5 Chairs since 2013 (Table 1). We also wish to nurture areas of existing strength and strategic importance and have appointed 17 Lecturers since 2013. We support staff to develop into research leaders, which is reflected in 48 successful academic promotions since 2013. We successfully supported two staff to be awarded UKRI Future Leader Fellowships (Mackinder, Lichman). We make strategic decisions about recruitment through discussions amongst our departmental management team, centre directors and research focus leaders, in order to ensure we are best able to take timely opportunities to appoint in respect to exciting new developments on the research horizon.

We are committed to facilitating the transition of Independent Research Fellows into academic positions, and two of our IRFs were appointed to lectureships in the REF period (Brackenbury, Dykeman), and two more have been awarded proleptic academic positions (MacDonald, Kent).

Equality and diversity

By Equality we mean that everyone has the opportunity to succeed.

By Diversity we mean that differences are to be recognised, respected and valued.

By Inclusion we mean that we create a research environment with practices and attitudes that recognise, respect and value differences.

We champion a culture that is inclusive, democratic and promotes gender, race and age equality. Biological Sciences at York has an international mixture of academic staff (34 nationalities), providing a diversity of cultural backgrounds. A testament to our success is our Athena SWAN Gold award. We were the first Biology department in Britain to receive an Athena SWAN Gold award (in 2014), which was renewed in 2018 reflecting our strong commitment to gender equality. Highlights of our Athena SWAN Gold award include:

1. Sustained success in increasing the number of female academics. Our female academic staff have increased from 28% to 35%, and increases are most pronounced for lecturers, where female lecturers have increased from 28% to 41%;
2. Successfully supporting women's careers and stemming the leaky career pipeline. Our actions around promotions have resulted in more women being promoted (an increase to 89% of females successfully applying for promotion, compared to 27% previously);
3. Raising the profile of women in biology as well as beacon activities to share best-practice, which have helped 13 other Institutions gain Athena SWAN departmental awards (including two Gold awards).

Our approach is simple: *good policies benefit all, while poor policies disproportionately affect those with protected characteristics.* Our **Equality and Diversity Group (BioEDG)** is chaired by the Deputy Head of Department with a remit to drive the Athena SWAN Charter and deliver our Gold Award Action Plan. Our policies include compulsory diversity and recruitment training and unconscious bias training, gender-balanced recruitment panels, flexible working, and equality-sensitive promotions criteria. During the REF period, we have had female representation at senior positions (including HoD (Potts), Deputy HoD for Research and Chair of the Departmental Research Committee (Hill), Deputy Head for Teaching & Staff (Helgason), Director of N8 Agri-Food Programme (Denby), Director of the Jack Birch Unit for Molecular Carcinogenesis (Southgate)). Women researchers are lead authors on two of our six Impact Case Studies. Our culture supports women to excel in biological sciences, and examples of women who have built their career foundations with us to subsequently go on to high profile careers include Professor Dame Ottoline Leyser FRS, CEO of UKRI, as well as our former HoDs since 2013 Prof Deborah Smith OBE (PVC for Research, University of York) and Professor Jennifer Potts (Head of School at the University of Sydney), and former Director of YESI Professor Sue Hartley OBE (PVC for Research, University of Sheffield). We promote a healthy work-life balance and inclusivity e.g. by scheduling Departmental meetings to start after 9:30 and to finish by 4pm. We support staff returning from periods of leave, such as parental leave or those with other caring responsibilities, with policies such as flexible working (5 staff in our REF return currently have arrangements to work part time) and research leave (see below). Staff returning from periods of sickness are offered a phased return. As a result of the COVID-19 crisis, our arrangements for remote working are robust and are supporting academic, research and Professional & Support staff to work effectively from home where possible. We can meet virtually to carry out much of the business that was once done only on campus, and we will discuss with staff which of these new arrangements are welcomed and will become part of our 'new normal' in future.

Our approach to REF2021 followed the processes set out in the University's REF code of practice in relation to the underlying principles of transparency, consistency, accountability and inclusivity, following the guidance from the REF Strategy Group, as well as termly REF briefings and Research Forums. We used the REF code of practice to determine research independence of staff, and at staff meetings for Biological Sciences, we kept staff informed of how outputs were selected for the portfolio. At regular intervals during the REF2021 period, we carried out an equality audit of the portfolio as it was being drafted to inform our selection. For example, we allocated multi-author papers to the female author when there was a choice. Throughout the REF2021 period, staff were supported by having the opportunity to apply for internal funding to complete outputs for inclusion on the portfolio. Our UoA includes 71 Category A staff (69.4 FTE; 31% women) and is broadly reflected in our outputs (174 outputs; 22% allocated to women), which have similar predicted GPA scores.

Supporting academic staff

We have policies to support the personal development and career progression of all our researchers. Our mechanisms to facilitate this include mentoring of new staff, and all new academic staff are given both a research and teaching mentor as part of their induction. Annual performance and development reviews are one-to-one meetings that are key mechanisms to identify needs of individuals (for instance the needs of part-time or fixed-term staff). These meetings provide the opportunity to signpost professional training such as the University's award-winning Leadership training programme [Princess Royal Training Award in 2016], including the Research Leaders training programme for early and mid-career research-active staff (*see IES, paragraph 22*) and funding and/or collaborations that would benefit their career development. We have trained 5 Mental Health First Aiders and provided Mental Health training for 60 staff.

We have also put in place a variety of processes to support our staff in carrying out their research successfully:

(i) Peer Review Colleges are aligned to our nine Fundamental Science Research Foci (Figure 1) and were introduced to nurture new initiatives, mentor staff in writing grant applications and enhance research collaboration (chaired by senior staff with UKRI peer review panel experience). Meetings to discuss the development of research projects are held on-demand and attended by researchers and staff from the Bioscience Technology Facility (BTF); these sessions help promote access to the world-class technology within the BTF, and provide supportive and constructive peer review to shape the researcher's ideas around new collaborations, innovation and impact of their research plans. Some of these sessions include representatives from industry, and managed through BioYork, to facilitate exchanges between academia and industry. Our Peer Review Colleges also provide feedback and advice on publications.

(ii) Administrative and technical support. We release academic staff from duties that can be undertaken more effectively by professional and administrative staff. We have in-house specialists in HR, Finance, IT, Health & Safety, Infrastructure Management, Supplies, Horticulture, and in our Electronics and Mechanical Workshops. Our Research Support Office assists with the preparation of grant applications and highlights new funding opportunities.

(iii) Research and impact leave policy. We encourage academic staff to apply for research leave of ~1 term every 3 years, recognising the importance of time to focus on research. Research leave is prioritised for staff returning from extended absences (e.g. parental leave, sick leave) or significant leadership roles (eg. HoD, Chair of Board of Studies, REF leadership). HoD, Deputy HoDs and Chair BoS also receive research support for their labs during their roles to ensure that research leaders are supported to perform these key management roles.

(iv) Research-teaching balance. We are proud of our excellent teaching and we believe that the best teaching thrives in a research-intensive environment, so that the next generation of bioscientists are trained by this generation's research leaders. All academic staff contribute to teaching, which is distributed in a transparent way through the shared **workload allocation model** that is fully transparent to all academic staff. Teaching and Academic Citizenship workload is balanced against Research activity, so that (i) newly appointed academic staff acquire new teaching and academic citizenship workload gradually over the first 3-4 years of their appointment, to allow them to focus on developing their research portfolio, and (ii) staff are released from other workload commitments if they have significant research grant income or PGR student supervision responsibilities. Efforts to balance staff contributions in teaching and research are supported by a team of Professional & Support staff and by 15 staff on Teaching & Scholarship (T&S) contracts. Our T&S staff allow us to excel in both teaching and research, and we provide a clear career development path for staff on T&S contracts; for instance, our Director for Students has a personal Chair.

(v) Promotions policy. Promotion opportunities recognise achievements in research, teaching and academic citizenship. The University regards impact (in the widest sense) as an important aspect

of research and gives it credit in academic promotions. While taking a lead in securing research income is an important promotion criterion, collaborative involvement in funding applications is also rewarded. Promotion readiness discussions are part of the annual Performance and Development Review process in the department. We recognise that some staff (particularly women) may be less likely to apply for promotion and so the HoD and Deputy HoDs actively encourage promotion applications in these discussions and support is given throughout the process.

Supporting technical staff

Our technicians are highly valued and make an important contribution to our research environment. York is a founding signatory of the **Technician Commitment** (https://www.technicians.org.uk/technician-commitment) and has been at the forefront of this initiative (*IES, paragraph 40*). We support our technicians to develop new skills and knowledge through our action plan that includes ensuring the recognition and career development of all our technical staff. The Bioscience Technology Facility is an excellent environment for technicians to develop high levels of expertise and advance their careers. Our technical staff often work as part of a team with academics to develop grant applications and advance research projects; their essential roles are reflected in our culture of including technical staff as co-authors on publications.

Supporting early career researchers and PDRAs

We support staff who have taken a career break to return to research through 50% matched-funded Daphne Jackson Fellowships (3 Fellows supported during the REF period). We also engage actively with the **Concordat to Support the Career Development of Researchers**. We support PhDs, PDRAs, Independent Research Fellows (IRFs), newly arrived ECRs and other staff with opportunities for professional development. Our departmental HR team includes a Training and Careers Officer specifically for PhDs, PDRAs and IRFs. Departmental decision-making is transparent: PhD and/or PDRA representatives sit on Boards of Studies, Departmental Research Committee, BioEDG and Staff committees. We have a Postdoc Society, which includes the provision of 'buddies' for new staff. We provide 1:1 career counselling, sessions on grant writing, opportunities to gain teaching experience, interview and CV preparation, an annual careers conference and drop-in 'Coffee and Careers' events, as well as mentorship by PIs. PDRAs can apply to the Departmental Research Committee for funding to employ a summer student, providing experience in writing proposals and managing research budgets and staff. We have recently introduced a scheme where PDRAs have been recruited to 20% FTE Teaching contracts, providing these academic-track PDRAs with opportunities to gain valuable teaching experience. We recognise the potential insecurity of PDRA careers, and the Departmental Research Committee provides salary bridging funds to promote continuity of employment between contracts. We offer support for Independent Research Fellowship applications, including an annual Fellowship Day and one-to-one support to develop their application. We have a dedicated training budget which ECRs can apply to for funding for external courses or to present at conferences that covers training and/or travel costs. Our staff also provide mentorships to ECRs through learned societies (e.g. Royal Society's early career mentoring network and British Ecological Society Women in Ecology Mentoring Scheme). Our PDRAs have had excellent success in obtaining tenure-track positions since 2014, reflecting our success in supporting ECR research during the REF period. Five PDRAs (Dykeman, Hewitson, Hawkins, Myburgh, Tonon) were appointed to lectureships at York.

We have strong policies in place to support our ECRs and embed them in our research community in Biological Sciences at York. New academics and IRFs are assigned an established academic as a mentor and an induction programme is developed for them. The York Post-Graduate Certificate of Academic Practice is mandatory for new lecturers, and includes both teaching and research-related training. New staff are given start-up funds and priority in applications for Departmental Research Committee funds. Success in our ECR development initiative is evident

in that, of four staff that we appointed to their first lectureship in 2013/14, three were promoted in the REF period, one to Senior Lecturer and two to Professor.

Research Students

Our goal is to train our postgraduate researchers with strong bioscience and analytical skills so they can work collaboratively across disciplines and communicate their research with other scientists and the public. We provide a research environment where they can gain the knowledge and expertise they will need to identify and tackle new questions and challenges in the future.

Our PGR student body

We host a vibrant postgraduate student body that contributes to research outputs, as well as to the dynamic social and intellectual environment of our department. Approximately 35 PGRs start their research studies with us each year and we currently have a total of 129 PGRs in Biological and Biomedical Sciences. Our research student population is composed mostly of UK students, with just over a quarter from overseas and elsewhere in the EU, and we have gender parity in PGRs (53% of our research students are female). About a quarter of our research students are self-funded, while most are in receipt of funding from research councils, charities or industry. Approximately 30% of our studentships are funded in part by industry. We are currently part of two Doctoral Training Partnerships (DTPs): the BBSRC White Rose DTP in Mechanistic Biology, and the NERC DTP Adapting to the Challenges of a Changing Environment (ACCE), and both have been successfully renewed and recruiting until 2024. Looking to the future, we joined the Discovery Medicine North (DiMeN) partnership with Sheffield, Leeds, Newcastle and Liverpool and are part of this renewal bid to the MRC. We were involved in a York-led inter-institutional £3.5M NERC CDT ECORISC bid that was applied for in May 2020 and subsequently awarded (with Cardiff, Exeter, Lancaster, Sheffield), focused on ecotoxicology and sustainable chemical use, which will fund 39 new PhD studentships. York Biology also receives a unique benefaction to the University by the Burgess family that has supported 4 fully funded PhD students. PGRs funded by medical charities (BHF, CRUK, Diabetes UK, Parkinson's UK) are provided with tailored training as a cohort and registered for a PhD in Biomedical Science.

Recruitment

Our commitment to our EDI aims has led us to develop recruitment processes that take positive actions to ensure we recruit a wide and diverse pool of research students. Positive, inclusive images are prominent in promotional material, online resources, and as part of recruitment at graduate fairs. Representative panels are selected for all stages of the PGR recruitment process including project sifting, the screening of applications and interviews. Our aim is to recruit a student body that reflects the full diversity of graduates in the UK and internationally. To widen participation, in addition to academic and research experience, our recruitment processes recognise and value many other competencies, including problem solving and motivation. All staff involved in interviews undergo unconscious bias training, with data from panels fed back to inform re-evaluation of procedures for subsequent cohorts. We monitor EDI data at application, shortlisting and recruitment stages and analyse these data for trends to assist with the constant re-evaluation and improvement of our EDI policies and procedures.

Training and Supporting our PGRs

Our research students have an exceptionally high rate of successful completion (95.5% during the REF period), which we attribute to our excellent training environment and supportive supervisory teams. Our UKRI-funded programmes require two supervisors, and we recognise this as good practice in terms of mentoring. Moreover, two supervisors allow students to build expertise in more than one area, and support interdisciplinary projects. Each PGR is also supported by a Thesis Advisory Panel (TAP), including additional academics with an interest in the student's well-being and the success of the project, who meet regularly to ensure the student is on-track for successfully completing their degree programme. We ensure that all PhD students undertake

training and development activities to maximise their effectiveness as researchers and prepare them for their next career step. Professional skills training is based around the **Vitae Researcher Development Framework** (RDF) such that all PhD students complete training for their own professional development and to understand and communicate research impacts from their project. We recognise that our students start their PhD with a wide range of previous experiences and, bearing that in mind, we provide wide-ranging opportunities, with flexibility for individuals to tailor their own training. To monitor their participation we use an online platform called SkillsForge that records their activities. When submitting their thesis, PGRs must also submit a portfolio outlining the development activities they have undertaken during their PhD. This portfolio includes a reflective piece on their professional development and research impact, and provides a repository of skills information, a valuable record that assists the student when applying for future career opportunities.

In addition to the training offered centrally by the University, professional development activities offered by us include training on poster and conference presentations, managing a scientific research project, preparation of CVs, job applications and teaching skills. We recognise that we are preparing our students for a data-intensive bioscience future, therefore we provide courses on programming, data analysis and data visualisation to ensure our students are capable of devising reproducible workflows to manipulate, analyse and model datasets that are increasingly large and complex. Many PGRs funded by our Doctoral Training Partnerships (DTPs) undertake a 3-month internship, gaining experience in a non-research, science-aligned career; during a placement, students develop additional skills valued by future employers. All PGRs are encouraged to participate in our Departmental Outreach Programme to promote their science to the public. Our students have an excellent record of engaging with national training and development opportunities such as the Biotechnology YES scheme.

Integration of PGR students into the research culture

PhD students are integral to the fabric of Bioscience research at York, where PGR representatives sit on many departmental committees, contributing ideas about research processes and strategies. We promote collaborative interactions among PGRs and other researchers through open plan write-up areas and lab space, providing a favourable environment for discussion and encouraging interdisciplinary research. PGRs make a significant contribution to our research; 30% of our publications during the REF period included our PhD students as co-authors, evidence that we are enabling students to perform high-quality research, benefiting them and our research.

The Bioscience Technology Facility (BTF) provides access to state-of-the-art equipment and research services, and the BTF staff are proactive in getting involved with PGR projects. The highly skilled BTF staff provide support and training to PGRs including monthly bioinformatics clinics and hands-on training courses such as confocal microscopy and cytometry. We run a funding scheme called "*PhD Facilities Awards*" that allows PGRs the opportunity to prepare and submit a mini-grant application for additional funding to use the equipment and services available in the BTF. This training helps to convert their ideas about how the latest technologies could further enhance their projects into fundable research proposals.

Our research seminar series feature several invited speakers each week and graduate students are expected to attend a weekly seminar. The York Biology Open Lecture series brings high profile scientists to York and gives our graduate students the opportunity for a post-lecture discussion with the speaker over lunch. The BBSRC and NERC DTP PGRs organise annual, student-run, multi-institutional symposia, including selecting presentations from submitted student abstracts, inviting plenary speakers, chairing sessions, and organising the programme. These symposia are well attended by researchers across our department and from the partner institutions. All of our PGRs present their research as posters and talks in the spring of each year as part of our annual Graduate Symposium. Prizes are awarded for best talks and best posters; we also run an annual "Research in Action" photography prize for our research students, and the winning photos are displayed as posters in the department.

3. Income, infrastructure and facilities

Research Income

During the REF period, we have increased the breadth and maintained a high level of funding, and ensured we recruit and nurture talented ECRs to grow our future research strategy. Our 5-year average (2015-16 to 2019-20) income from UKRI has increased by 58% from REF2014 (£4.2M) over the current REF period to £7.2M, largely due to our success in securing funding in industrial biotechnology (see below). The total income for Biological Sciences was £78.4M which is a sixth of the University's research income (2013–14 to 2019–20) (Figure 2). Our average annual research income over the assessment period per FTE was £161,428, which puts York twelfth in the Russell Group, underpinning our high levels of research activity throughout the REF period.

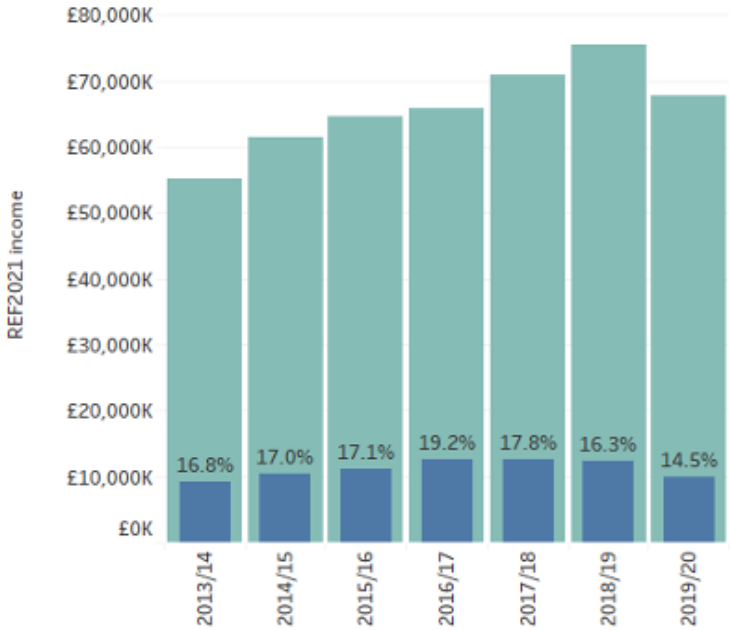

Figure 2. Biological Sciences income as a percentage of University of York income.

Research income has been secured from a broad range of funding sources over the REF period providing resilience for our research activities. For charities, Wellcome Trust awards included Investigator Awards to Kaye (£2.3M), and Mottram (£1.7M), an Innovations grant to Kaye for vaccine development (£1.6M) and Sir Henry Dale Fellowships to Fogg and MacDonald. Kent ($1.5M) was funded by The Bill & Melinda Gates Foundation for stem cell gene therapy and since 2007 Graham (total to date = $27M) has developed hybrid plants for production of Artemisinin. Hitchcock (£1.25M) and Kent (£1.5M) received CRUK Programme Foundation Awards and Southgate (£1.3M) a York against Cancer award for the Jack Birch Unit for molecular carcinogenesis. C. Thomas secured £10M from the Leverhulme Trust to establish the Leverhulme Centre for Anthropocene Biodiversity. Major awards from UKRI span the research councils, including from the MRC programme grants to Mottram (£1.8M) and Kaye (£2.4M). Hill led a NERC Highlight project to examine species evolutionary responses to climate change (£1.4M). York is a UK leader in Industrial Biotechnology and our strength in this area has led to a number of major BBSRC awards including four BBSRC Networks in Industrial Biotechnology awards to Graham (£3.1M) McQueen-Mason (£2.4M), two BBSRC Strategic LOLAs to McQueen-Mason (£1.9M) and Bancroft (£1.3M), and three UK IB Catalyst Awards to Graham (£2.4M), G. Thomas (£3M) and

White (£2.7M)). Bruce has secured funding for Environmental Biotechnology from the US Department of Defense (£1.3M). We also benefited from EC awards including two Marie Curie ITN awards to Kaye and Bruce (Total £1.7M), H2020 awards to McQueen-Mason (£1.5M) and an ERC Starting Grant to Brockhurst (£0.9M). Industrial funding includes £2.2M to Graham from Sun Pharmaceutical Industries.

Financial support for the development, promotion and dissemination of research and impact

We support all stages of research and development of impact from priming research ideas to networking, dissemination, translation and outreach. During the REF period, funding has been provided for these activities by: (i) Departmental Research Committee (DRC) (£174,341), (ii) UoY Central Research Priming Fund (£567,382), (iii) N8 Agrifood pump priming (£62,720), (iv) Global Challenges Research Fund (GCRF) pump priming (£250,242) and (v) Centre for Future Health (Wellcome Trust; CFH research priming and early career fellowships) (£2M). DRC funds provide support to ECRs to generate preliminary data to pump-prime full grant applications. We collect demographic and gender information on grant submission and success rates to inform our strategic support for all of our staff, and focus resources. DRC also provides paper-completion and conference travel grants to assist dissemination of research findings, and ring-fenced funding for PDRA and technician training.

Infrastructure and facilities provision

Bioscience Technology Facility (BTF)

The BTF houses world-class technologies in one facility, and exemplifies our strategy of encouraging collaboration between disciplines to solve fundamental and applied biological challenges. The BTF attracted over £3M (2015-2019) of further funds and expanded into new areas of technology at the forefront of bioscience research and now hosts over 90 key instruments with a value over £10M. This has included the first commercial Nanostring DSP (£600k) in Europe, Waters Synapt (£766k), Nanotemper Prometheus (£120k), Zeiss Elyra 7 super-resolution microscope (£522k) and first Atmospheric CLEM JEOL SEM (£450k). The investment in the Nanostring platforms in York allowed us to be responsive within extremely tight timelines and provide a unique resource to the UK Coronavirus Immunology Consortium. All five BTF labs (Genomics & Bioinformatics, Imaging & Cytometry, Metabolomics & Proteomics, Protein Production and Molecular Interactions) have significant investments with 25 new major pieces of equipment installed, whilst on-going collaborations with instrument manufacturers have provided access to a further £500k/year of equipment, through beta-testing collaborations. The BTF facilitates multidisciplinary research in York as well as with external academics (59 institutes) and commercial companies (47 companies ranging from large Pharma e.g. AstraZeneca and GSK through to SMEs e.g. StreamBio, Elucida).

The impact from our research is further disseminated through the BTF running international training courses for delegates to receive hands-on training on BTF equipment. These training courses ensure that best practices are followed and new techniques can be quickly adopted, thereby disseminating York expertise across the globe. Over the COVID-19 period, the BTF set up online Royal Microscopical Society forums on establishing safe working practices in Light, Flow and Electron Microscopy labs in the COVID-19 era, which attracted >300 participants from over 25 countries.

Horticulture Facility

The Horticulture team manages Biological Science's extensive controlled-environment plant growth estate. The facilities include high precision controlled-environment cabinets and walk-in controlled temperature rooms, as well as glasshouses and small-scale outdoor field plots. The Facility supports bio-secure research using GM plants, microorganisms and quarantine plant pathogens. The facility offers a plant husbandry service, including a growing media and pot filling

request service, provision of plant material for research, maintenance of glasshouses and controlled environment facilities, advice on plant cultivation and selection of equipment and materials, experimental design using controlled-environmental facilities and the monitoring and provision of environmental data.

Centre of Excellence in Mass Spectrometry (CoEMS)

This is a joint initiative of the Departments of Biology and Chemistry that provides a highly specialised technical service to academia and industry. The core-supported and multidisciplinary nature of CoEMS contributed to successful EPSRC funding in 2015 (£1.4M), which was used to purchase Thermo Orbitrap Fusion Tribrid and Endura mass spectrometers (MS), which have been used for metabolomics, proteomics, and quantitative small molecule characterisation. In 2018, successful BBSRC ALERT funding (£766k) was used to purchase a Waters Synapt G2Si MS system.

York Structural Biology Laboratory (YSBL)

This world-leading structural biology laboratory which won the Queen's Anniversary Prize in 2019 for pioneering work in protein molecular research is located in the Bioscience building and includes staff working in the biosciences (Potts, Plevin). Staff at YSBL are pioneers in new methods of crystallisation and many of the crystallisation screens marketed worldwide were invented at York. YSBL is renowned for particular computational methods used by crystallographers worldwide, including new approaches in molecular replacement and refinement as well as increased streamlining model building into electron density. The Departments of Chemistry and Biology were awarded £1.6M by the Wellcome Trust in 2019 enabling a new cryo-EM facility to be established in YSBL.

High performance computing facility

The University has recently invested £2.5M towards a new HPC facility (Viking), which provides biological sciences staff with the latest computing infrastructure for all their computational workloads (*see IES, paragraph 41*). As part of this investment, the University provides a number of free courses in popular programming languages and help and support to access these facilities. Additional support is provided through storage for datasets, providing 1-2TB of free storage for all principal investigators. We will also be building a cost-effective storage solution for large datasets. Recognising the importance of impact in research, the University also provides a dynamic web hosting platform, and virtual machines, free of charge, allowing research to be published to the web in dynamic and interesting ways, and allowing the public and researchers to interact with it. In addition to providing commodity and research services, the University also has a team dedicated to research computing. In addition to a Head of Research Computing, based centrally, there is an embedded team of two research software engineers and an HPC Linux expert. These staff are based in Biology, Physics and Chemistry, but as part of a wider strategy they support research across the institution, and are actively involved in central HPC development.

Cross-HEI sharing and collaborative use of research infrastructure

We actively support the N8 Research Partnership initiative to promote and facilitate regional inter-university sharing of major items of equipment across the eight most research-intensive Universities in the North of England. Potts was on the NMR Assets Sharing group, and our Director of Infrastructure and Facilities is responsible for regularly updating the N8 equipment database. We commonly support grant proposals for equipment that will be shared within the White Rose and N8 Universities (e.g. Light Sheet microscopy shared with Leeds, and CyTOF with Newcastle) and we have support from other N8 University partners for our own equipment purchases (e.g. Nanostring DSP). We also routinely host external academics (from ~25 Institutes/year) to provide access to our high-end instrumentation within the BTF as well as to transfer best practice in the use of high-end instrumentation through direct one-to-one optimisation.

Major benefits-in-kind

The BTF is active in technology development and has formed research alliances with equipment companies for beta-testing and applications development. For example, the BTF was the first beta-test site for the world's leading confocal microscope, Zeiss LSM880 AiryScan (Germany), and the BTF was the UK demonstration site for the Zeiss LightSheet for 12 months. The BTF also hosts the concept, beta-test and demonstration of PhaseFocus (UK) microscopes, and a new collaboration with Tomocube (South Korea) involves beta-testing their new digital holographic microscope. JEOL (Japan) have continued to loan their FEG-SEM and the BTF was their worldwide demonstration site for ClairScope, a combined light- and electron-microscope. Other examples include beta-testing the Beckman Coulter (USA) new generation flow cytometers and sorters and Oxford Nanopore's single molecule nanopore sequencers. All of these developments are dependent on expertise in the BTF and access to fully-supported key technologies. Many equipment manufacturers support training courses run by the BTF, providing technical experts, direct sponsorship and the provision of additional systems for our international courses, giving access over an extended time. In turn, we have been involved in training many external staff in using their company's own products. Consultancy agreements have been made with equipment manufacturers, including Bruker, Zeiss, Phase Focus, Tomocube, Beckman Coulter, and Oxford Nanopore, providing our staff with access to the latest technologies and advanced training.

Hence our infrastructure and facilities provision is exceptional and vital for under-pinning our world-class research activities.

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

Research collaborations, networks and partnerships

Collaboration is at the heart of our research strategy, structure, appointments (sections 1 and 3), and shared facilities (section 3: e.g. Centre for Excellence in Mass Spectrometry joint between Biology and Chemistry and YSBL), resulting in >80% of our staff co-authoring a publication with one or more academic staff at York. Further evidence that successful collaboration underpins our research activity comes through analysis of our REF2021 outputs, which shows that 93% have at least one non-York author, 64% involve UK co-authors and 72% include international co-authors; with 33% of our grant applications involving UK and international collaborators across five continents (Figure 3).

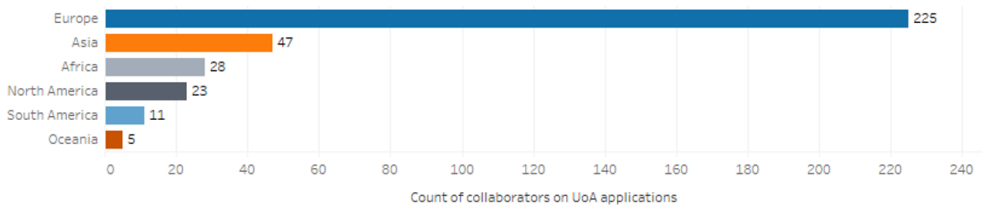

Figure 3. Collaborative grant applications submitted during the REF period (Europe includes 151 UK collaborative applications).

All staff are encouraged to engage in collaborative initiatives through annual performance reviews, criteria for promotion, access to travel funds and pump-priming grants to establish links. Our Industrial Placement and Industrial Liaison Officers, working with the University's Research & Enterprise office facilitate visits and placements, for example in 2019, they organised year-long placements for 44 students and enabled 20 academic and research staff to visit 22 businesses and other institutions. In addition, YESI, YBRI and BioYork have Research Facilitators to support interactions with industry/NGO/policy partners. We support visits and secondments with potential

partners to develop ideas beyond initial contact, and successful collaborations have led to a Royal Society Industrial Fellowship with Yorkshire Water (Chong). We provide departmental resources for workshops and conferences in which external partners participate (e.g. the YESI 5-year Anniversary event in 2018) and fund travel to attend meetings where contacts with prospective non-academic partners can be made. Staff have successfully responded to external opportunities to establish inter-institutional networks. For example, we led an EU Marie-Curie Innovative Training Network (ITN) with 7 other European Universities, AstraZeneca and Lonza Chemie (Bruce) and another ITN with 7 other European Universities and MedImmune and Miltenyi Biotech (Kaye).

Staff have led major collaborative initiatives, such as the BBSRC Networks in Industrial Biotechnology, where HVCfP (Graham) and LBNet (McQueen-Mason) both had ~800 industrial partners during the NIBB phase 1 period (2014-2018). The N8 Agrifood consortium (based in Biology at York), is very active in forging new research collaborations in agri-food resilience through provision of pump-priming funds and networking activities. YESI co-ordinated the successful Leverhulme Centre for Anthropocene Biodiversity bid. York Biological Sciences leads or is a major contributor to five international networks (JCPiL, PrevPKDL, LeishChallenge, leishPathNet, Global Network of NTDs) that aim to find innovative solutions to leishmaniasis.

Responsiveness to national and international priorities and initiatives

We support staff to respond to international and national initiatives by providing administrative support and pump priming, leading to awards from GCRF and the Newton Fund. Examples of projects to address environmental and health challenges and improve livelihoods in the Global South include: reducing industrial waste from sugar cane processing in India (McQueen-Mason), biorefining of oil palm residues in Malaysia (Bruce), peatland restoration in Indonesia (Hill), developing rice with increased resistance to salinity and drought (Maathius), development of new tests to help clinicians decide on the best course of treatment for leishmaniasis (Kaye), characterisation of an epigenetic regulator of Leishmania spp. virulence (Walrad) and characterising the key biological processes of *Leishmania chagasi,* the parasite that causes Visceral Leishmaniasis (Mottram).

Wider contributions to the economy and society

We encourage staff to participate in impact-related activities. The majority of our staff undertook impact-relevant activities during the REF period, such as involvement in spin-out companies (Cizzle Biotech, Coverley), collaborating with businesses (e.g Novozymes, GSK, Prozomix, Sun Pharmaceuticals, Fujifilm Diosynth, Unilever, UbiQ, Ubiquigent and Novartis), disseminating knowledge, and engaging with policy makers, indicating that active engagement and participation in impact activities is widespread and embedded within our culture.

Translate and commercially exploit research for economic and societal benefit

Our staff participated in impact-relevant training during the REF period, such as departmental and UoY courses and briefing sessions in enterprise (including start-ups) and IP. The Research and Enterprise Office assists with IP, overseeing licensing agreements with East-West Seed to commercialise CNAP's *Artemisia* varieties (see Impact Case Study); sufficient seed has been sold to make over 62 million anti-malarial treatment courses for malaria sufferers in the developing world. Our centres facilitate research translation, this ensured rapid progression from discovery to impact for our two industrial Impact Case Studies e.g. CNAP collaborated with GSK Australia (now Sun Pharmaceuticals) to develop a new high yielding noscapine–morphine poppy; noscapine is used in cough medicines and is undergoing clinical trials as an anti-cancer compound. This work has generated a novel supply chain that represents 100% of Sun Pharmaceuticals commercial production of noscapine in 2018 (over 25 metric tonnes, sufficient for 1.6 billion doses; see Impact Case Study). CNAP Chairs Bruce, Bancroft and Graham were BBSRC Innovator of the Year finalists in 2014, 2015 and 2016, respectively.

How the unit engages with diverse communities and public through its research

We are strongly committed to public engagement and outreach activities to inform the public about science and our research. Examples include, Pint of Science, SoapBox Science York (led by Biology (Hill) and reaches more than 5000 members of the public), Festival of Ideas, YorNight, Cafe Scientifique and podcasts. We have also had speakers at all YorkTalks events since their instigation, which provide a day of public engagement talks highlighting world-leading research at University of York. We deliver a range of talks and hands-on activities for local schools. YESI (2019) organised a workshop in Jordan for experts on waste management in refugee camps, with participants from the UK, Jordan, Palestine, and Israel, and as part of the workshop they visited the Zaatari refugee camp. The University Press Office provides assistance with press releases and distributing them to the media, sets up interviews, and disseminates information and images.

Our PhD students actively engage with external organisations in many inspiring ways and we include a few examples here. Our PGRs established 'GreenSTEMS', a society aimed at facilitating collaboration between social scientists and scientists from STEM on environmental and sustainability issues. GreenSTEMS are involved in local public engagement activities including the University's Annual Festival of Ideas and the UK Space Agency Outreach day (2016). Our PGRs run workshops at primary and secondary schools across Yorkshire, including one focused on Women in STEM.

Indicators of wider influence and contributions to the research base

Journal editorships

26 staff including ECRs contributed to journal editor and editorial board roles for over 38 journals during the REF period demonstrating academic citizenship is widespread among our staff. This includes being editor-in-chief *Microbiology* (G. Thomas) and *Ecological Entomology* (Hill) as well as editorships e.g. *Molecular Plant* (Davis), *Journal of Experimental Botany* (Denby), *Global Change Biology* (Hartley), *Ecology Letters* (Hill), *HemaSphere* (Kent), *Frontiers in Cell and Developmental Biology* (MacDonald), *Functional Plant Biology* (Maathius).

Membership of Research Council or similar national and international committees

Our staff play crucial roles in the strategic developments of funders. Graham is a member of BBSRC Council. Bruce is a member of BBSRC Bioscience for renewable resources and clean growth strategy advisory panel, and was a member of BBSRC Industrial Biotechnology and Bioenergy Strategic Advisory Panel, and a BBSRC panel member for the mid-term review of the Synthetic Biology Centres. Hartley is a member of the BBSRC Strategy Advisory panel for Food and Agriculture, Chair of the BBSRC Gene Drive Working Group, Chair of the BBSRC/NERC/ESRC Sustainable Agriculture Research Innovation Club, Chair of the Science advisory board for BBSRC/NERC Achieving Sustainable Agricultural Systems, and Member of the Royal Society Global Environmental Research Committee. Mottram is a member of the Wellcome Trust Science Interview Panel and the ERC Immunity, Infection and Immunotherapy Consolidator Grant Panel. Kaye is Chair of the Infections and Immunity Board at the MRC, a member of the MRC Strategy Board, Chair of the MRC National Mouse Genetics Network Oversight Board and Chair of UKRI/DHSC COVID-19 Rapid Response, Rolling Call and Agile Call funding panels. Hill is Chair and core-panel member at NERC and in-coming member of Science Committee. Staff regularly sit on UKRI grant panels including BBSRC, MRC and NERC as well as learned societies that provide funding for research (e.g., Royal Society). Hartley (YESI) prepared two post-Brexit agri-environment briefing papers for the Secretary of State and gave evidence to the Environment Audit Committee in Westminster.

Fellowships, awards and prominent recognition

Graham was elected Fellow of the Royal Society in 2016, elected to EMBO (2016) and awarded the Biochemical Society Heatley Prize (2017). Chong was awarded a Royal Society Industrial

Fellowship (2016). ECRs Lichman and Mackinder successfully obtained UKRI Future Leaders Fellowships, and Fogg and MacDonald obtained Wellcome Trust Fellowships. Hartley is a Trustee, Royal Botanic Garden Kew (Prime Ministerial appointment), and Trustee, Castle Howard Arboretum Trust. She was President, British Ecological Society (2016-17) and is a Board Member, Natural England (Secretary of State appointment) and was awarded an OBE in 2019 for her services to Ecological Research and Public Engagement. Plevin and Potts are members of the York Structural Biology Laboratory (YSBL) whose long-standing excellence of ground-breaking research in protein science was recently recognised with a 2020 Queen's Anniversary Prize.