**Institution:** University of Birmingham

**Unit of Assessment:** 5 – Biological Sciences

## 1. Unit context and structure, research, and impact strategy

### 1.1 Structure of research across the submitted unit

*Summary*

UoA5 sits within the School of Biosciences, which is one of four schools in the College of Life and Environmental Sciences (LES) [REF5a, 1]. UoA5 comprises four coalescent, strategic themes to which each member of research staff is primarily affiliated. However, collaborations extend across themes and units to share facilities, develop new initiatives, and to examine large scale scientific questions, often using interdisciplinary approaches. Since 2014 we have:

- Recruited 25 new staff, bringing our BAME and gender balance in line with the UK HEI national population;
- Increased our average annual grant income by 18.7% (including major projects detailed in next section);
- Invested £46.4M in new research infrastructure, equipment, and facilities, for example, the Birmingham Institute of Forest Research (BIFoR), which includes the Northern Hemisphere's only Free Air Carbon Enrichment (FACE) experiment;
- Increased funding for doctoral research training through the award of five externally funded doctoral training programs;
- Produced 1479 Scopus listed outputs with 35,475 citations (24.0/publication) and overall field weighted citation of 2.61; building on collaborations with 62 international institutions, 62% of our outputs have international co-authors;
- Established several major commercialisation opportunities, notably two spinout companies;
- Influenced national and international policy through staff secondments and panel memberships of government and non-governmental organisations;
- Shaped current and future research agendas (detailed in next section).

*Unit Structure*

Category A submitted staff (60.8 FTE) and research-intensive teaching staff (19 additional staff) in UoA5 are structured around four research themes, each led by senior academics:

- **Microbiology and Infection (M&I)**
- **Plant Sciences and Food Security (PSFS)**
- **Cells and Molecules (C&M)**
- **Biosystems & Environmental Change (BEC)**

*Microbiology & Infection (M&I, 23.7 FTE)*

The M&I theme focuses on greater understanding of microbial function for both beneficial bacteria and important pathogens. M&I research was strengthened through the creation of the cross-College (with Medical and Dental Sciences) Institute of Microbiology and Infection (IMI) in 2011. This has grown, during the last six years, to become one of the largest groupings of microbiologists in Europe, with an outstanding reputation. The cross-disciplinary nature of M&I within IMI has been pivotal for attracting high profile researchers (*Ballou*, *Banzhaf, Crouch, Frickel*, *Mercer* and *Tsai*). It has also enabled staff to respond rapidly to infectious disease challenges of international concern, including the West Africa Ebola and South American Zika outbreaks and, recently, the COVID-19 pandemic (*Loman, Quick, Dafforn*). Key developments since 2014 are:

- **The election to FRS of** *Besra* for his pioneering work on *Mycobacterium tuberculosis* cell wall metabolism, joining *Busby* FRS.
- **£19.5M research income** (BBSRC, MRC, Wellcome Trust, Leverhulme Trust).
- **The appointment of two colleagues as Government Chief Scientific Advisors** for BEIS (*Dafforn*) and the Food Standards Agency (*May*).
- **Contributed to two spin-out businesses** (MicrobesNG (CSO *Loman*) and Linear Diagnostics Ltd (*Dafforn*)).
- **Pioneering COVID-19 research** as key players in the £20M COVID-19 Genomics UK Consortium (COG-UK) (*Loman* and *Quick,* a UKRI Future Leaders Fellow), and through technology development by *Dafforn* and *Knowles* to study COVID-19 Spike protein interactions with human receptors and develop the world's fastest COVID diagnostic assay.

Research from the group is highly influential, with M&I staff contributing to three Impact Case Studies (*Loman* and *Dafforn* x 2).

Key future targets are to:

1. Maximise national and global influence of M&I researchers through development of a national Centre;
2. Build a world class reputation in host:pathogen interactions that links to research in other disciplines (e.g. medicine, plant pathology);
3. Develop strategic industry partnerships and strong translational links to clinical practitioners to develop barrier-free translation of research that can be used to benefit society.

*Plant Sciences & Food Security (PSFS, 15.2 FTE)*
PSFS theme members investigate the fundamental principles underpinning plant growth, development, and environmental interactions, using fundamental and applied approaches, and through strategic links with industry. Their work is intrinsically linked to the growing issue of Food Security and Climate Change, and directly addresses global research priorities. Investment in new staff has enabled the theme to focus on the globally challenging issues of plant pathogens, crop breeding and tree and forest responses to climate and pests and diseases. Key developments since 2014 are:

- **Recruitment of 9 new staff, net increase of 7** (59% of total PSFS);
- **Capture of research income of £9M** including UKRI Research ERC starter grants, EU multi-partner grants and a Marie Curie ITN grant;
- **Establishment of the Birmingham Institute of Forest Research (BIFoR)** [REF5a, 4.2.3] to study the impact of climate, pests and pathogens on tree and forest performance;
- **Capture of £2.5M of philanthropic donations** to establish tree pathology research (*Luna Diez*, *Kettles*, *Jackson*).

The theme also provides an Impact Case Study (*Maxted*) who is a global lead on policy development for protection of Crop Wild Relatives.

Key future targets are to:

1. Ensure sustainability of crop yields in stressful environments to safeguard resilience and secure food production;
2. Work with M&I colleagues to develop host-microbe interaction research;
3. Extend BIFoR influence and reach for tree and forest policy development.

*Cells & Molecules (C&M, 13 FTE)*
The C&M theme makes fundamental discoveries in neurogenetics, RNA processing and membrane protein biology for the benefit of human health. The theme includes strengths in Drosophila research (neurogenetics and RNA processing) and translational work to develop novel therapies for leukaemia and lymphoma. Research is further enabled by leadership in advanced mass spectrometry for the analysis of biomolecular and chemical structure, and for metabolite identification in human aging and diseases. Key developments since 2014 are:

- **Attracting £12.2M in research income** (BBSRC, EPSRC, Wellcome Trust, Blood Cancer UK, BHF, Leverhulme Trust);
- **Expansion of Advanced Mass Spectrometry Facility** led by *Cooper*, an Advanced EPSRC Fellow, through membership of the Rosalind Franklin Institute;
- **Co-hosting the Phenome Centre Birmingham** co-directed by *Dunn;*
- **Launching of the REPAIR-MDS clinical trial** funded by Blood Cancer UK (£1M) as the first ever UK randomised trial for myelodysplastic syndrome patients (*Bunce*).

Key future targets are to:

1. Strengthen neurogenetics research through collaborations with Birmingham's Institute for Mental Health and Centre for Human Brain Health to facilitate translational outcomes;
2. Enhance research in membrane receptors for therapeutic targeting;
3. Increase links to pharmaceutical industry by enhancing translational work from their drug discovery pipeline.

*Biosystems & Environmental Change (BEC, 8.9 FTE)*
BEC members synthesize pure and translational research to quantify, monitor and mitigate against anthropogenic-induced environmental change and damage. The theme's goal is to provide leadership in discovering causal links between environmental change and the functional responses of organisms and their ecosystems. Key developments since 2014 are:

- **£9.1M research income** including two NERC Hotspots on adaptive evolution and ecological relevance of eDNA in freshwater (£1.9M);
- **Research/Impact Fellowships** from the Leverhulme Trust, the Royal Society and NERC (*Thorpe* (x2), *Chappell*);
- **Launch of a new commercial trading division** supplying environmental 'omics facilities and expertise, to provide cutting edge services to industry;
- **Creation of the Environmental Care Consortium (ECC)**, a new charitable foundation.

BEC's research generates substantial public interest, including >£1.3M in media-related advertising value equivalent**;** BEC has also contributed to an Impact Case Study which focuses on enhancing the welfare and conservation value of captive Great Apes across the globe (*Thorpe, Chappell and Myatt*).

Key future targets are to:

1. Develop a world-leading cross-School partnership for Global Change Biology and Sustainability;
2. Work with ECC to confront global health and justice problems;
3. Build cross-disciplinary research (e.g. M&I, UoA7/14) to tackle 'one health' global challenges.

*Group synergies and influence*
Our future plans are ambitious, focusing on enhancing synergies between research groups in UoA5, and more broadly across the University and beyond. We are levering technological developments to make advances across the biological science and related disciplines (see 1.2.1). Importantly, we are now a nexus for large scale research programs that address global challenges. An example is the recent award of the UoB's largest ever EU grant (£19.3M) on Precision Toxicology; this combines empirical science and social science disciplines across institutions to address both science and policy challenges. This will ensure that the outstanding research led by UoA5 translates to real policy and practice changes.

We have expanded our external influence with increasing numbers of staff holding senior positions in science policy (i.e. two Chief Scientific Advisors, *Dafforn and May*). Our research has also had impact in the commercial sector via a successful spinout business (MicrobesNG), significant contributions to another (Linear Diagnostics Ltd) and the establishment of a new University trading division (Environmental Omics Facility), providing cutting edge genomics to industrial partners.

*Research strategy and management*
In 2019, we evolved our Research Strategy (2020-2026) (see 1.2.2). The strategy is based on a whole-unit consultation and the University's research strategy, alongside influences from the external research environment. Delivery of the strategy is the responsibility of UoA5's Research Strategy Group (RSG), which reports progress against KPIs to the School Executive Committee. The RSG meets monthly and comprises our Heads of Research, Knowledge Transfer, PGR, Research Theme leads and mentors, an early-career research representative, and research grant/business engagement support from Professional Services; the group has a 5:5 M:F split.

*Our commitment to EDI*
UoA5 actively promotes an inclusive environment that is supportive to all constituents, believing that diversity and inclusivity drive innovation, ensuring our research is exciting, creative, and pioneering. We strive to ensure that EDI is embedded in all operational and decision-making activities, and EDI is a standing agenda item on all School Committees. Our EDI Committee (which reports directly to the School Executive Committee) includes academic and professional services staff, full and part-time staff, and postgraduate researchers; members represent a range of disabilities, ages, ethnicities, religions, and sexual orientations. In the last 5 years, we have delivered on our commitment to shortlist equal numbers of F:M applicants for research posts (1951 posts in total); this led to 9.7% more females than males being appointed to all research posts. Of the total headcount, 14.4% of staff identified as BAME (12.1% did not disclose their ethnicity) matching the University-wide figure, and higher than the average in UK HEIs (13%).

**1.2 Research objectives**

**1.2.1 Achieving the 2014-2021 research objectives**
Since 2014, we have received £46.4M infrastructure investment to develop and sustain a rich, vibrant, and agile portfolio of research across all thematic areas. We have 33% more staff, increasing our proportions of BAME and female staff in line with the UK average, enabling us to grow our research activities. Notably, we have grown UK Research Council funding by >11% year-on-year since 2014.

Our research ethos is one that embraces **new technologies** and breaks down traditional disciplinary boundaries, enabling us to tackle research through a truly multidisciplinary approach. These investments have enabled us to fully support this ethos and actively target our five major goals set in our REF 2014 submission:

1. Enhancement of metabolomics
2. Development of imaging as a key technology
3. Growth of research in plant sciences and food security
4. Growth of drug discovery efforts in microbiology
5. Establishment of synthetic biology as a research area

*1. Enhancement of metabolomics*

**The Phenome Centre Birmingham was established in 2016** with a £7.1m investment from MRC, Industry and UoB [REF5a, 4.4] leveraging a strategic partnership with ThermoFisher Scientific of >£1.5M and **external collaborations** with the Defence Science Technology Laboratory and AstraZeneca >£2.5M**.** The Centre has developed and implemented new data algorithms for bioinformatics. The capabilities and strength of the Centre were crucial for the award of the £19.3M EU grant in 2020 to *Colbourne* and *Viant*, to lead Precision Toxicology in Europe. The Centre is established as a trainer of commercial scientists providing a wide range of courses both face-to-face and digitally. The appointment of an industry Professor, *Professor Ruth Roberts* (member of the Academy of Toxicological Sciences Board and Society of Toxicology Council), was made to increase the group's interaction with industry and policy makers (see point 4).

*2. Development of imaging as a key technology*

Researchers in UoA5 were central to establishing the Centre of Membrane Proteins and Receptors (COMPARE) [REF5a, 2.1.5]. COMPARE provides access to state-of-the-art microscopes (including light-sheet, dSTORM and PALM instruments) alongside dedicated technical and computational support. COMPARE is inherently interdisciplinary, linking up our researchers with those in the other STEM-focussed Colleges [REF5a, 1], to develop new instrumentation and methods in response to the needs of our researchers. COMPARE has also been fundamental in supporting recruitment of staff (e.g. *Frickel*, *Mercer*).

*3. Growth of research in plant sciences and food security*

We have invested substantially into plant science research to help with the global effort of securing sustainable food production. This includes recruitment of one of the world's most highly cited plant scientists (*Foyer*) alongside outstanding early career scientists via our highly competitive Birmingham Fellows institutional scheme (a recruitment scheme which provided proleptic lectureship appointments for outstanding early career staff) [REF5a, 3.4.1] and direct appointments. These include *Compton* & *Gibbs* who were Birmingham Fellows before REF2014 and *Sanchez-Moran,* a BBSRC David Phillips fellow; their seniority and excellence have been instrumental in attracting, and supporting, others. Our increasing reputation for plant sciences has also attracted external fellowship holders (*Labandera* (Leverhulme) and *Plackett* (Royal Society URF)).

Since 2014 we have established BIFoR with UoAs7 and 14, with external investment in infrastructure and staff costs, **including a £15M philanthropic donation from the JABBS foundation, matched by in-kind investment of >£15M by the University** [REF5a, 4.2.3]. BIFoR allows us to challenge experimental paradigms, innovating in interdisciplinary science in novel ways to produce outcomes not previously available. We recruited scientists from traditional crop science to work with trees (*Luna-Diez*, *Kettles* and *Busch*) and widen expertise in ecology and physiology. New staff appointments have been supported by four fellowships, including a BBSRC Future Leaders Fellowship, a Royal Society University Research Fellowship, and a Leverhulme Independent Fellowship, and six direct appointments. To support this new cohort of researchers, we have **invested £1.1M in a state-of-the-art Glasshouse facility,** with a further **£1M contribution from the Wolfson Foundation** [REF5a, 4.2.3]. We secured £1.04m for the Leverhulme Trust-funded Forest Edge doctoral training program, enabling a cohort of 20 students to have training in high quality interdisciplinary research and, in partnership with

agricultural experts at Harper Adams University, to develop applied plant sciences expertise through the BBSRC MIBTP DTP.

*4. Growth of drug discovery efforts in microbiology*
Our recruitment of *Ruth Roberts* (founder of APCONIX) has catalysed the development of drug discovery science in UoA5. *Ruth Roberts* has used her experience to analyse the opportunities that exist in UoA5 for drug discovery, establishing a project pipeline and advising academics on next steps required to advance projects towards commercial development. This also contributed to **£800K in funding to establish the Centre for Drug Discovery and Development ($CD^3$),** including £300K from the Wellcome ISSF and £500K from the University's Dynamic Investment Fund (DIF) [REF5a, 2.1.2]. *Ruth Roberts* has worked closely with other members of staff to establish drug screening in UoA5. The centre is a **partnership with Evotec**, a large multinational drug company that specialises in partnering with research organisations to de-risk potential drug leads. A monthly **Drug Discovery Club** has been established to support lectures given by academics and external speakers from the pharmaceutical industry. Dedicated Drug Discovery Ambassadors provide support to researchers in developing potential projects that will utilise the centre. These activities have led *Alderwick* to a **flagship licensing agreement** in 2019 with a spinout company in China (Legion Pharma) to develop novel TB therapies, whereas *Dafforn* has successfully commercialised novel reagents for use in global drug discovery (see REF3).

*5. Establishment of synthetic biology as a research area*
Since 2014 a distinctive research effort in Synthetic Biology, based on materials science, has been established between UoA5 and Chemistry and Chemical Engineering. This has been supported by **an award of £560K from the Defence Science and Technology Laboratory (DSTL) to support eight PhD studentships.** The outputs from these projects led to an award of £400K from the centre for Defence Enterprise to develop novel materials (*Mackaskie*). The UoA has also had significant influence on public policy makers through *Dafforn,* who was **Entrepreneur-in-Residence** (see REF3) responsible for Synthetic Biology at UK Government (BEIS).

**1.2.2 Our 2020-26 research strategy**
We are a key contributor to the University of Birmingham's strategic objectives for the next 5 years [REF5a, 2.4]. Our ambition is to become one of the top Biosciences units in the UK, and globally, through the attainment of our core goals to:

- Be international leaders in the excellence and impact of our research, evidenced by high quality publications and impacts.
- Be the preferred partner for global academic, industry, and end-user partners in our fields of expertise, evidenced by increased co-funding and outputs and an outstanding international reputation.
- Have staff that are diverse, happy, motivated, successful, and collegiate, ensuring that they develop rapidly to their full potential.

*Overarching strategic objectives*
To achieve these goals UoA5 has identified the following overarching objectives that build on the strengths and ambitions of our Research Themes (see 1.2.3). These will:

- **Build an inclusive research culture** in which our staff at all career stages:
  - achieve their goals in world class research, irrespective of gender and race;
  - are mentored, encouraged, and celebrated for their achievements;
  - are empowered to be ambitious, entrepreneurial, and multi-disciplinary.
- **Build a diverse bioscience workforce of the future** by recruiting and providing the highest quality training to our PGRs and PDRAs.

- **Harness the importance of technology innovation and multidisciplinary teams** in future bioscience research.
- **Embed impact generation** in line with the eight guiding principles of the forthcoming UUK Knowledge Exchange Concordat as a pillar of our research culture; increasing business and end-user engagement; and funding and developing pioneering global alliances to address key global challenges.

**1.3 Enabling and facilitation of impact from our research**

We recognise the importance of funding to develop both fundamental and applied sciences, leading to demonstrable impact that has economic or societal benefits. To enable this, we use the vast enterprise experience of our Head of Knowledge Exchange (*Dafforn*) and broader Research Strategy Group (RSG) along with colleagues in professional services, to promote understanding of impact in its widest form from policy and know-how, to new products and technologies. UoA5 has successfully utilised >£180,000 of the University's BBSRC Impact Acceleration Account (IAA) plus some funds from a College impact budget (£50-80K annually) for activities ranging from commercialisation opportunities (*Browning*), people exchange (*Thorpe*), and public engagement activity (*Hidalgo*).

**1.3.1 Impacts on commerce and the economy**

*Collaboration with commercial entities*

The commercial impact of our research is supported by a dedicated business engagement partner (BEP) [REF5a, 4.1], and the Head of Knowledge Exchange, who reports to the RSG. We also use peer-to-peer coaching to increase BE and academics who have been involved in commercialisation (e.g. *Dafforn, Ruth Roberts, Alderwick*) provide lectures on their experiences and 1-to-1 advice and guidance. Since REF2014 UoA5 has obtained **£1.69M in industry income**, facilitated by working with 86 industrial partners. This has included **26 iCASE awards and industrial PhDs since 2014** (e.g. *Borrill*, *Catoni*, *Foyer*, *Gibbs*) with businesses including both large corporations (e.g. Unilever, AstraZeneca, BASF, Syngenta, Enza Zaden) and SMEs (e.g. Domainex, BioBest, RAGT Seeds Ltd, KWS Ltd). Research contracts include research with international businesses like Sanofi and NovoNordisk. We have also built strategic relationships with ThermoFisher Scientific (worth >£1.5M) to support our development of mass spectrometry.

*Generation of Intellectual property (IP)*

Staff enterprise training is a key element of catalysing the generation of IP. Our staff are encouraged to attend the University's Medici commercialisation training course (five staff have completed the course) [REF5a, 2.1.3] and other external courses (four staff have completed the BBSRC Enterprise fellowship). We also enter a student team into the BBSRC YES competition each year. The commercial impact of our research is supported by the BEP [REF5a, 4.1] and the Head of Knowledge Exchange, who reports to the RSG.

Since August 2013, researchers in UoA5 have **filed 41 patents (32 granted)**, with a license income of £89K. Using this IP, researchers have contributed to two spinout businesses. *Dafforn* has licensed three patents to Linear Diagnostics Ltd, a clinical diagnostics business which has since raised more than £3M in investment (see REF3). *Loman* founded MicrobesNG, a microbial genome sequencing service, which has customers in more 30 countries (see REF3). Both businesses are currently accommodated in the BIOHUB incubator, which is <10 minutes' walk from the School. Our Genomics facility (led by *Orsini*) has become an independent trading division, to offer its unique capabilities commercially. *Dafforn* has also successfully licensed patents on protein encapsulation to a business in the Netherlands, enabling it to sell new reagents across the globe (see REF3).

**1.3.2 Impact on Policy**

*Secondments*

As part of our yearly appraisal process, our staff are encouraged to undertake secondments to promote mobility of personnel into key roles and ensure our work has the greatest potential to influence public policy. For example:

Professor *Tim Dafforn's* secondment to BIS as Entrepreneur-in-Residence for Synthetic Biology led to his appointment as Chief Scientific Adviser (CSA) to BIS and then BEIS. His activities (see REF3) included a co-authored letter to the Prime Minister, which led to changes in government entrepreneurship policy focused on supporting emerging technologies, like Synthetic Biology. Our drive to maintain input into policymaking has continued with the appointment of Professor *Robin May* as the CSA for the Food Standards Agency in 2020. Professor *Nigel Maxted* has provided crucial advice to the UN Food and Agriculture Organisation influencing both UK and EU policies, including the UK Agriculture Bill (see REF3). Professor *Susannah Thorpe* has advised DEFRA on legislation that guides the licensing and regulation of the UK zoo industry, while Dr *Steve Unwin* joined a specialist panel for UNEP GRASP (Great Ape Survival Programme) in October 2020 to advise on preventing the next pandemic caused by zoonotic disease.

*Integrating external policy makers into UoA5*

We use our research as evidence to support new policy making and thus interact with people and organisations that can facilitate this. For example, as part of the BIFoR establishment, Professor Nicola Spence, Chief Plant Health Officer from DEFRA has an honorary position to advise on policy implications of the BIFoR work program. We have appointed a range of external scientists and experts (e.g. Dr Anna Brown, Head of Tree Health and Contingency, Forest Research; Dr Caroline Ayre, Confor) to the BIFoR Advisory Board, helping to shape BIFoR activities and strategies, as well as acting as a conduit for disseminating outputs and shaping policy. The new Precision Toxicology consortium has a Stakeholder Advisory Group with international group members to advise on research activities and disseminate information. Members include: European consultant Dr Christopher Portier who previously served as U.S. Director of the National Center for Environmental Health at the Centers for Disease Control and Prevention and Director of the Agency for Toxic Substances and Disease Registry U.S., Dr Apolline Roger, Chemicals Lead at the London-based NGO ClientEarth, Dr Fiona Sewell, Scientific Program Manager, National Centre for the Replacement, Refinement and Reduction of Animals in Research (NC3Rs), Professor Maurice Whelan, Head of the Chemicals Safety and Alternative Methods Unit of the European Commission Joint Research Centre.

**1.4 Supporting interdisciplinary research**

Our development of interdisciplinary research has been enabled by our involvement in leadership of major cross university research institutes:

- **Institute for Microbiology and Infection** with UoA1;
- **Birmingham Institute of Forest Research** with UoAs7 & 14 [REF5a, 4.2.3];
- **The Phenome Centre Birmingham** with UoA1 [REF5a, 4.4];
- **COMPARE** [REF5a, 2.1.5] (see section 3.2);
- **Ecolaboratory river and pond mesocosm facility** as part of a £1.2M investment by the University with UoAs7 & 14;
- **The Henry Wellcome Building for Biomolecular NMR.**

Our recruitment and training of postgraduate students is supported by **five major multidisciplinary doctoral training centres**, BBSRC MIBTP2020, NERC CENTA2, two Wellcome programmes (MIDAS and AAMR) and Leverhulme Forest Edge.

MIBTP2020 and CENTA2 involve universities and external partners from across the region, and both have successfully renewed and enlarged since 2014.

At the heart of our Research Strategy is a recognition of the increasing importance of interdisciplinary team science in the global research effort. To catalyse the growth in this activity we will:

- Embed increased inter-theme research into the future aims of our research themes (section 1.2.3).
- Increase our interdisciplinary links across the University building on key experiences: e.g. Precision Toxicology, a collaboration with social science (UoA18); BIFoR collaborations on forest research with UoA7 and UoA14; M&I microbiology research via IMI and collaborations with UoA1.
- Grow our external interdisciplinary and interscholastic activity, by encouraging staff to increase their exploitation of existing networks (e.g. $CD^3$, BIFOR, MIBTP2020, CENTA2) to develop research programmes. We will encourage more staff into positions of influence (via secondments or to join grant panels) and support more staff to take advantage of funding schemes that expand their research horizons beyond UoB.

**1.5 Progress towards an open research environment**

The UoB is a signatory recognising the principles of the Concordat on Open Research Data [REF5a, 2.2] thus researchers in UoA5 are engaged in ensuring UoA5 has developed an open research environment that will transition to a state where research data is made openly available for use by others where possible. We will:

- **Increase awareness and improve staff skills in open research** through local activities, including sessions at School meetings and away days alongside provision of training through the University Library.
- **Ensure alignment with the Concordat on Open Research Data** by signposting our staff to specific training to highlight opportunities for open data sharing via subject-specific repositories and the UoB Research Portal.
- **Ensure Open Access to our publications** by authorising Green self-archiving of all research outputs on the Institutional repository PURE and encouraging the use of Gold Open Access publication venues. We also encourage applications to UoB Library funding for Gold OA of key papers [REF5a, 2.2]; and support posting of pre-prints in appropriate subject-specific repositories such as bioRxiv e.g. UoA5 researchers posted 57 papers on bioRxiv in 2017-19 which have subsequently been published in peer review journals.
- **Encourage our staff to promote their work to non-specialist audiences.** Professor *Alice Roberts* (Professor of Public Engagement in Science) has a prominent profile in Life Sciences communication in the broadcast media and press. *Alice Roberts* supervises PhD students and lectures to UG students in the School, and oversaw the introduction of UoB's Public Engagement strategy. Many other staff are active in a diversity of public communication fora such as Café Scientifique, special events at the Thinktank, Birmingham's biggest science museum), The Big Bang show at the National Exhibition Centre and Festival of Science. Our staff make increasing use of social media; the recent appointment of a School communications lead (*Tomlinson*) aims to highlight our research. Research carried out by our staff is also highlighted in the *Birmingham Brief* and *The Conversation* as online fora for communication and commentary on research findings.

### 1.6. Ensuring a culture of research integrity

Research integrity and ethical practice are central to all research activity in UoA5 from undergraduates through postgraduates to staff. Our research follows the central University Code of Practice for Research and University-level ethical review processes. All new research projects and postgraduate research projects undergo internal ethical review [REF5a, 2.2]. Two UoA5 colleagues (first *May*, now *Jackson*) chair the University Advisory Group for the Control of Biological Hazards to ensure colleagues adopt best practice and work within the appropriate legal framework.

## 2. People

### 2.1 Staffing strategy

Our staffing strategy is led by the principles of People and Culture theme of the University's draft 2021-25 strategic framework and its commitment to "developing a research culture that stimulates and nurtures; is inclusive, equal and diverse and recognises the importance of recruitment and induction, through to support progression and retention" [REF5a, 2.4]. Our commitment to equality, diversity and inclusivity is recognised through the award of UoA5's Athena SWAN Bronze award in 2016, with a new application due for submission in late 2021.

Through adherence to these values, the UoA5 research population has grown in the last six years, with 60.8 FTE (16.1 F:44.7 M) research-active members of staff compared to 42.8 FTE in 2014. The current percentages of academic staff at each grade are: 33.9% Professor, 8.1% Reader, 22.6% Senior Lecturer, 24.2% Lecturer and 11.2% Research Fellow.

The BAME staff population in UoA5 (14%) includes 13% of Research fellows, 17% of Senior Lecturers and 12% of Professors.

Our staffing strategy has focused on four aims:

1. **Recruitment of new staff** to complement and grow areas of international excellence, expertise, and critical mass;
2. **Increasing the diversity of our workforce;**
3. **Enhancing succession and leadership;**
4. **Increasing the number of independently funded research fellows.**

We have focused recruitment to strengthen our international reputation in microbiology and infection (8 FTE) and maintain the upward trajectory of our plant sciences theme to a world-class reputation, as well as starting the new BIFoR research institute (10 FTE). In these cases, recruitment focussed on key strengths to create capacity and capability to tackle large scale research problems.
Our recruitment process aims to maximise diversity by:

- Mandating unconscious bias training for recruitment panel members and staff more widely;
- Targeting female, BAME and other underrepresented candidates through subject networks;
- Use of gender-neutral language and highlighting support offered to University staff;
- Contextualising outputs/achievements in relation to career breaks during shortlisting and interviews;
- Only approving shortlists if there is realistic gender balance.

The University is a signatory to the San Francisco Declaration on Research Assessment (DORA) [REF5a, 2.2], and we follow its principles in our assessment of academic job applicants. During our recruitment processes we highlight our working practices and policies that provide a supportive environment for applicants of all backgrounds.

Equality & Diversity (E&D) training opportunities include training on Unconscious Bias, inclusive development, chairing inclusive meetings and being an LGBTQ+ ally [REF5a, 3.4.3]. The regular school bulletin has highlighted positive role models around work/life balance and caring, and information on events such as Women in Science, Black History Month, and staff LGBT and BAME networks.

The COVID crisis has accelerated our adoption of new technology (e.g. Virtual Conferencing) that enables participation by all, thus all meetings can now be accessed remotely.

**2.2 Staff development strategy**

Throughout their career, our staff are provided with opportunities to assess and reflect on their current capabilities, develop plans to increase capabilities in areas of need and then action those plans. This process is supported by a yearly performance and development review (PDR) [REF5a, 3.4.3] for all staff including postdoctoral researchers. New staff arriving in UoA5 on their first open academic contract undergo induction and then a probation process that supports their career development to future successes.

**2.2.1 Induction and training**

An accepted offer of employment initiates the induction process. All new staff are required to attend a University induction day and complete mandatory training [REF5a, 3.4.2]. In addition, UoA5 arranges a pre-arrival meeting with the School Head of Operations ensuring that research facilities and movement of staff and equipment occur efficiently. Upon arrival, meetings are set up with a pre-defined list of people, including the Head of College (HoC), Head of School (HoS) and College Directors of Research and Education. At College level, there is an induction webpage, which brings together information about College resources and University induction into one place.

**2.2.2. Staff probation process**

The probationary period for permanent academic staff at the University is normally 3 years. Within the first 8 weeks after arrival the probationer works with the HoS to develop a **Probation and Personal Development Plan (PPDP)** [REF5a, 3.4.3]**,** which is approved by the Head of College. Probationers are encouraged to attend relevant courses provided by People and Organisational Development (POD), the University staff development unit. At this stage, in consultation with the probationer, a mentor will be assigned to act as a guide for the probation period. Meetings between the probationer and HoS are then held at regular intervals (typically every 6 months) throughout the 3 years of probation to reflect on progress, review, and where relevant, modify or add objectives. Every 12 months the PPDP is reviewed by the HoS and HoC.

**2.2.3 The Performance and Development Review (PDR)**

Once through probation, academic staff enter the annual PDR appraisal; PDRs are conducted by a team of trained senior staff. All PDR reviewers undertake training and attend refresher training every five years. Data from the last three years show that **PDR completion levels in this UoA are >95%** (a few staff are unavailable for review due to leave etc.). The PDR discussions include promotion and training, leadership development, and longer-term career planning, including flexible and part-time working, career breaks, and succession planning. The PDR also captures future research planning, including strategies for research funding applications and awards. This includes flagship training schemes provided by the University's POD unit to support transition through career stages. Since 2014, **20 members of UoA5 staff (6**

**females) have participated in these flagship training schemes** [REF5a, 3.4.4]. As part of our efforts to support increased promotion for female staff, 4 (*Borrill*, *Compton*, *Cunningham*, *Thorpe*) have participated in the national AURORA leadership programme. Once the PDR process is complete each case is reviewed by HoS and any issues actioned.

**2.2.4 The promotion process**
Staff are strongly encouraged to consider their promotion strategy during their PDR in June/July. Those interested meet with the HoS, who provides advice and assigns an appropriate staff member as a mentor. Promotion criteria and decision timelines are clearly described on the HR webpage and signposted to all staff. The College also runs annual promotions workshops to provide further advice to individuals considering applying for promotion.

The University is explicitly committed to equality in the promotions process:

- **Equality guidance documentation available to all staff** on the Human Resources website;
- **The career pathways for part-time staff are equivalent to full-time staff;**
- **All staff on promotion panels complete E&D training.**

The current research staff base of 60.8 FTE is 17 females (F) and 45 males (M). Since 2014, 16 staff were promoted to Senior Lecturer (4 F, 12 M), four to Reader (2 F, 2M) and seven to Professor (2 F, 5 M). Given the nature of the 1:2.7 F:M pool ratio, female members of staff have been at least as successful as male. For promotions to Reader and Professor success rates for female staff have been higher than for male. There has been an improvement in the diversity of external recruits; 12 / 25 (48%) staff recruited to UoA5 were female, including 50% of external Professor appointments, since 2014.

Wider evidence of the success in our career development process is that **four Biosciences staff (two female) have been promoted to senior University leadership** roles: *Hotchin* (Director of Postgraduate Research, now (HoS); *Minchin* (Director of the Birmingham International Academy); *Myatt* (Acting Dean of Liberal Arts and Natural Sciences); *Pritchard* (College Director of Education).

**2.2.5 Specific support for postdoctoral researchers (PDRAs)**
We support the developmental aspirations of PDRAs through alignment to the 2008 Concordat to Support the Career Development of Researchers recommendations. Our PDRAs are formally supported by the Postdoctoral/Early Researcher Career Development and Training (PERCAT) Initiative [REF5a, 3.3].

UoA5 has gender balanced representation on the PERCAT committee (*Browning*, grade 8 and *Lee*, grade 9: both also sit on the institutional early careers research committee). Our PDRAs also influence national PDRA development debates e.g. *Lee* is an elected member of the UKRI working group for Postdoctoral Researchers development.

**2.2.6 Recognition for staff delivering research and impact**
Our workload model calculates research, impact, teaching and administrative load, using weightings based on best practice in the UK. Data are gathered on an ongoing basis and inform discussions in PDR meetings. Our workload philosophy with respect to research is that where new grant or impact activity has been secured, teaching and admin roles are altered accordingly. In doing so, we provide ring-fenced time for both research and impact activities. The model also includes a standard tariff for citizenship duties and implicit FTE-adjustments for part-time staff and is monitored annually for gender bias. Data show that, since the introduction of this model, there has been an equitable workload gender balance in UoA5.

In line with the forthcoming Knowledge Exchange Concordat, impact has equal importance to frontier research in recognition and reward and is reflected in promotion criteria [REF5a, 3.4.6]. A clear case of this was the promotion of *Thorpe* and *Loman* to Chair based on both excellent research and impact (see REF3). We believe that role models are essential for driving culture change and staff with expertise in this area provide mentoring and support for those wishing to impact society from their research.

**2.2.7 Support for Doctoral Research students**

Doctoral Researchers (DRs) are integral to UoA5's research strategy. We have a large and diverse community of DRs: since the last REF, 79 Home/EU and 69 overseas DRs have completed their PhDs, of which more than 50% were female. Submission rates for the last five cohorts are 84% with a completion rate of 91%. Approximately 40% of DRs are recruited from outside the EU, while 9% of UK DRs are BAME. Since 2014, we have been a **partner in 7 Doctoral Training Grants** funded by UKRI, Wellcome Trust, Leverhulme (Forest Edge) (88 DR). A further 30 DRs have been funded via other funding mechanisms including The Darwin Trust of Edinburgh (3-4 studentships at UoB p.a. for non-UK students studying for a PhD in molecular microbiology) as well as individual NERC and EPSRC studentships. We have also secured studentship income from the EU, the Commonwealth Scholarship Commission, charities (Wellcome, Bloodwise, BHF, Cancer Research UK) and philanthropic donation. We have been awarded 26 iCASE awards with businesses in the UK**.**

DRs are supported centrally by the University Graduate School at the Westmere Hub (opened in 2015 to provide training and a social space for all DRs [REF5a, 3.2]). At a unit level we are committed to fully supporting the development of our DRs through alignment with the Graduate School's Researcher Development Framework by:

1. **Providing a 3-person supervisory team for each DR** that includes the supervisor, a co-supervisor, and an academic advisor whose role is to advise on academic practice and progress of the project;
2. **Tracking of student training via Development Needs Analysis (DNA)** based on the Vitae Researcher Development Framework;
3. **Supporting the international DR population** by providing bespoke language support through the Birmingham International Academy (BIA);
4. **Mandating monthly meetings between DRs and supervisors** to discuss progress that is recorded on the University GRS online system;
5. **Making regular supervisor training compulsory.**

DRs are represented on the Biosciences Graduate Research Committee, the College Postgraduate Research Committee, chaired by the College academic PGR lead, and through this are represented on the University Graduate Research Board. We carry out an annual review of PGR provision which includes input from DRs and is overseen by the University Graduate Research Board and the University Quality Assurance Committee. DRs edit the internal School Newsletter and invite and host external seminar speakers. UoA5 holds an annual Graduate Research Symposium, organised by the PGR community with participation from all staff.

Our DRs play an active part in University life through, for example, '3 Minute Thesis' and 'Images of Research' competitions run by the DRs (and open to MSc and BSc project students) as well as the annual, University-wide Research Poster Conference, which brings together DRs from all parts of the University.

Doctoral Researcher wellbeing is enabled by all DRs having a mentor who is an academic member of staff to whom DRs can approach for independent, confidential advice on all aspects of their PhD. Our DRs are also supported by a 'buddy' scheme in which every new student has a senior DR allocated at the beginning of their study. DRs can access the School Student

Wellbeing Officer, who is employed by the College to provide pastoral and mental health support to members of UoA5. The officer provides a daily drop-in service, as well as services provided by the University Student Hub, including Counselling, Wellbeing, Disability, Mental Health and Learning Support.

**2.2.8 Support staff**

The final core element of our research population is our support staff. Over the last five years our research has been supported by an average of 53 Professional Services staff who are split between project specific support and wider support of facilities and infrastructure. The College Research Support Office (RSO) comprises a large team that provides the school with a dedicated research facilitator (*Jasmine Penny*). The RSO mobilises a team of staff for larger bids that require complex support, working closely with the Development and Alumni Relations Office (DARO), EU and International team, Business Engagement and Research Contracts teams to put a bespoke package of support around these bids. We also utilise the expertise of the Strategic Projects and Partnerships (Life Sciences) team for strategic projects, such as bids to establish new Centres (e.g. The Phenome Centre) and Doctoral Training Partnerships (e.g. MIBTP). DARO plays a pivotal role in liaising with academics and philanthropists to develop projects that utilise donations (e.g. BIFoR). Research activities are also underpinned by a number of technical-services staff who organise H&S support, run a stores and workshop for bespoke services, and manage logistics for space and facilities. UoB is one of the original signatories of the Technician Commitment, a UK wide initiative to promote technicians across HEI and develop their skills and careers. Support staff in UoA5 utilise the Technical Academy in UoB which allows for skills sharing across the University as well as other institutions, particularly across the Midlands [REF5a, 4.4]. The University Wellbeing Service, including a Counselling Service, Harassment Advice Service, Employee Disability Service, and a Mediation Service, is available to all staff enabling them to make informed decisions about work and personal issues [REF5a, 3.4.5].

**2.3 Our commitment to staff and student equality and diversity**

We are committed to enhancing the equality and diversity of the people working in the institution; UoA5 holds Athena SWAN Bronze status which was renewed in 2016. The gender profile of Biosciences Research Staff is a ratio of 1:2.7 females/males. Analysis of recruitment data and focus groups shows no evidence for systematic bias in appointments or promotions. Over the last six years we have encouraged gender and BAME equality in appointments and promotions explicitly. For example, we are fully supportive of flexible working arrangements. We have staff at all levels who have flexible working arrangements, including senior leaders. The Biosciences Equality and Diversity Committee monitors the effectiveness of these policies, chaired by a Deputy HoS and reporting to the School Executive Committee (SEC). Demographic data is actively consulted on all recruitment and promotions decisions, including the composition of internal panels and committees**.** Equality and Diversity and Unconscious Bias training are mandatory for all staff involved in recruitment and promotion.

We also consider staff working patterns and where required, we deploy technological solutions to enhance flexibility. All meetings and research seminars occur in family-friendly hours (9:30 – 16:00). Gender, part-time working, caring responsibilities, and flexible working are central factors when SEC allocates tasks to staff. During the last six years the number of women holding a Chair has increased from two to eight and the College has appointed its second successive female Head of College. **Six of the 12 independent ECR fellows appointed since 2016 are female.**

Over the last six years we have increased the number of women in prominent senior leadership positions in the School e.g. **the key roles of Head of Research (*Thorpe*), Head of Education (*Lodge*), Deputy HoS (*Cooper*), Head of Admissions (*Cull*).** We aim to ensure equal

representation on all committees in the School, which has been aided by the growth in female staff over the REF period; female committee representation is 47% (H&S) and 43% (Research). SEC explicitly considers gender when making these decisions alongside part-time working. For example, the current Head of Research is on 0.9FTE contract accommodated through flexibility in the meeting schedule and the use of video conferencing. Our success in this effort is evidenced by the observation that seven of the twelve committees in UoA5 have female chairs.

Specific examples of events aimed at supporting women are the Women in Science lunch group (led by *Luna Diez*), BAME, Parent and Carers, Rainbow, and the University-level Women's professor networks. Women in Science lunches are open to all. We also provide funds to assist with costs of childcare specifically to enable School Seminar speakers who might not otherwise be able to attend.

**3. Income, infrastructure, and facilities**

**3.1 Income**

Since the REF2014 period, UoA5's strategy to focus its research to exploit cutting edge approaches has yielded a very significant increase in income from a wide variety of sources (comparisons are from REF2014 period vs REF2021 period):

- An **18.7% increase in average annual research income,** from £7.1M p.a. to £8.4M p.a.;
- A **67% increase in average annual income from the EU,** from £0.73M to £1.21M;
- A **112.8**% **increase in UKRI and Royal Society income** from £18.7M to £39.8M;
- A **diversification of funding from new sources** e.g. £0.7M funding from non-UK charities compared to essentially zero previously.

This includes 29 awards with other UK universities, 19 with EU collaborators and 23 with researchers outside the EU.

These significant successes have been achieved by providing a support structure for staff grant writing enabled by our research support teams [REF5a, 4.2]. These teams provide:

1. Research funding intelligence that is targeted at specific researchers;
2. Training on bid writing with special focus on ECRs and fellowship writing;
3. Support throughout the bid writing process including finance;
4. A proof-reading service to ensure bids are of high quality and meet funding criteria.

In addition, central University teams support larger bids providing strategic support and secretariat to large multicentre bids (see 2.2.8 above).

**3.2. Infrastructure**

Over the last six years UoA5 has benefited from **£46.4M of investment into research infrastructure** (from internal funding and UKRI and charitable donations). This includes £5m investment to upgrade and refurbish the existing Bioscience estate. Key investments are:

*The Birmingham Institute of Forest Research (BIFoR)*
The centrepiece of BIFoR [REF5a, 4.2.3] is a 20-hectare mature forest site that is a living laboratory to study the reaction of forest ecosystems to the combined threats of climate change, invasive pests, and diseases. BIFoR has the **only Northern Hemisphere Free Air Carbon Dioxide Enrichment (FACE) facility.** BIFoR is co-led with UoA7 and UoA14 and includes 14

PIs, 5 PDRAs and 5 DRs in UoA5. Recently the JABBS Foundation donated a further £2M to develop tree pathology (*Jackson* was recruited to lead this new development). BIFoR academics currently receive funding from NERC, JABBS, the Woodland Trust, the Wolfson Foundation, the Leverhulme Trust, and the John Horseman Trust.

*Centre of Membrane Proteins and Receptors (COMPARE)*
A **£10M interdisciplinary imaging centre** was created with a joint investment from Birmingham and Nottingham [REF5a, 2.1.5]. It provides state of the art imaging facilities including light-sheet, dSTORM and PALM instruments. The centre also supports interdisciplinary research projects by linking data analytics and instrumentation applications experts and bioscientists.

*The Phenome Centre Birmingham*
**This is a multidisciplinary and multisite facility** [REF5a, 4.4] linking mass spectrometry in the Biosciences building, The Henry Wellcome Centre for Biomolecular Spectroscopy (HWB•NMR) and a targeted assay and clinical trials facility in Medical and Dental Sciences. The centre was established with £8M from the MRC, £1.7M from four scientific instrument companies (including ThermoFisher Scientific) and £0.5M from the University of Birmingham; this included £800K for laboratory refurbishment. The collaborative research aims to improve our mechanistic understanding of human diseases and ageing, to identify targets for interventions and to provide approaches for stratified medicine for prognosis, diagnosis, and treatment.

*Henry Wellcome Centre for Biomolecular Spectroscopy (HWB•NMR)*
This is the largest open access high-field NMR facility in the UK. In 2018, UoB won a **£6.5M investment from UKRI/EPSRC** to host a cutting-edge 1 GHz spectrometer [REF5a, 4.4]. HWB-NMR is unique in the UK, both in terms of the highest available field strength (1 GHz) for solution phase work, and the line-up of NMR spectrometers available at a single site (600, 800 MHz and 1 GHz). The open access programme offered by the facility has been financially supported by the Wellcome Trust since 2004 and recently has been renewed to 2023 with a £1.5M award over 5 years.

*The Advanced Mass Spectrometry Facility (AMSF)*
This is located within UoA5 and has received £1.5M from EPSRC and BBSRC and £1.8M investment from the University [REF5a, 4.4]. The centre includes a **strategic industrial partnership with ThermoFisher Scientific** who provide benefit-in-kind access to their latest instrumentation and software. *Cooper*, one of very few women to gain an EPSRC Advanced Fellowship, directs the AMSF and two specialist scientific officers support the instrumentation portfolio. The AMSF develops innovative methods of Mass Spectrometry imaging and proteomics and their application to cell signalling, cancer, and tissue repair.

*Birmingham Environmental Research Facility*
The newly developed glasshouse facility [REF5a, 4.2.3], funded through a £1M Wolfson Foundation award and £0.2M charitable donation, alongside £1.1M UoB investment, provides a series of controlled environmental chambers to study the interactions of plants and biological systems with physical and biological environmental stressors. The facility represents an **interdisciplinary collaboration between staff from UoAs 5, 7 and 14**.

*Other institutional facilities*
Researchers in UoA5 are also supported by several institution wide facilities. These include:

- MidPlus-Bham, the University's archive for long term storage of datasets associated with published papers
- The Birmingham Environment for Academic Research (BEAR) that offers secure data storage including collaborative storage (BEAR DataShare)

- BlueBEAR, a high-performance computing resource comprising of 168 nodes [REF5a, 4.5], which includes CaStLeS (a computer environment with access to 3 PetaBytes of storage) dedicated to the needs of the life sciences.

**3.2 Infrastructure, facilities and expertise used to create impact**

In 2014 the University undertook a root and branch restructure of Impact support. For business engagement this meant the establishment of a dedicated business engagement team [REF5a, 4.1] with partners placed in each College, but with central coordination. The LES College BEP supports UoA5 academics throughout the process of establishing and executing a collaboration with an industrial partner. This has supported UoA5 to obtain £1.69M in direct industrial income as well as in-kind provision (e.g. our strategic relationship with ThermoFisher Scientific which underpins the Phenome Centre) over the REF period.

If research has generated commercialisable IP, then the University's technology transfer office, University of Birmingham Enterprise (UoBE) [REF5a, 4.1], provides help and support to the academics. This is complemented by a unit mentoring scheme where academic staff skilled in technology transfer, e.g., Dafforn, provide 1:1 support on a researcher's specific needs to guide them through the process. UoBE provides a full suite of support from training via its flagship Medici Scheme [REF5a, 2.1.3], through patent filling and licensing, and the establishment and growth of a business. Its dedicated spin-out team (that currently supports the business in *Dafforn's* impact case study) helps academics setup a business and find investors. In many cases initial investment is also available through the University's own seed investment fund. In the last six years the University has also established a purpose-built Bio-incubator (The BIOHUB) on campus which can house early stage spin-outs and has recently committed to constructing the new Birmingham Health Innovation Campus (BHIC) which will provide scale-up facilities for emerging businesses from 2023 [REF5a, 4.2.2]. UoA5 are engaged in the BHIC through the proposed Birmingham Precision Medicine Centre as well as wider entrepreneurship.

UoA5 has successfully worked with Development and Alumni Relations Office (DARO) [REF5a, 4.1] to engage with philanthropic giving from our alumni and charitable trusts to support our research impact. This relationship was crucial to facilitate the £17.5M gift that underpins our BIFoR institute and provides for support in other areas including our work on Great Ape Welfare.

**3.3 Cross HEIs and shared facilities (UK and overseas)**

Across HEIs, we participate in the Midlands Innovation [REF5a, 2.1.5] regional equipment sharing 'catalogue', involving UoB and the Universities of Nottingham, Leicester, Warwick, Aston, Cranfield, Keele and Loughborough. This structure allows UoA5 to maximise its access to equipment while at the same time aligning with the infrastructure usage guidance from UKRI, which aims to minimise the wastage of facilities. For example, this provides direct access to high specification Cryo-Electron Microscopy Facilities in both Warwick (Tomography) and Leicester (Titan Krios) extending cellular and molecular imaging capabilities. Connections with Aston University provide access to Lipidomics and membrane protein production facilities to enhance UoB facilities.

**3.4 Benefits-in-kind**

Both the Phenome Centre and BMTC (see 4.1) have received **more than £1.5M in in-kind benefit** in terms of instrument loans and service contracts because of strategic links to instrument manufacturers.

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

Our research collaborations are generated at several levels to enable us to reach our research goals. At a unit level we see these collaborations as essential to provide intellectual and technical breadth to projects that would not be possible using expertise solely in UoA5 (see section 4.4 for multidisciplinary engagement activities).

**4.1 Economy**

Our influence on the economy encompasses both working with existing businesses to increase profitability and creating entirely new business collaborations. This includes projects generated by industry need and projects based on translation of new research findings. These projects together have been worth a cumulative total of £1.69M of income into UoA5 over the last six years.

Our activities with business have a strategic focus around four sectors that best map areas of expertise in UoA5 to sectors of R&D spend: Pharmaceutics and Diagnostics, Agriculture, Environmental Monitoring and Omics technologies, and the Zoo sectors).

Over the REF period we have had funded projects with **11 pharmaceutical businesses and a diagnostics company** including large multinational corporations and SMEs (*Dafforn*: Sanofi, NovoNordisk, Heptares, UCB, Domainex, MSD, AstraZeneca, Lonza), (*Alderwick*: Signature Discovery, Apconix), (*Cooper*: UCB), and in the Diagnostics sector (*Dafforn*: Linear Diagnostics Ltd, see impact case).

Our work with the Agricultural Sector has also yielded a significant number of research collaborations (*Bassel, Gibbs, and Dafforn:* Syngenta, LimaGrain, ASB Agri) while our strength in omics technologies (environmental and medical) has allowed us to establish projects with the consumer products sector (*Viant*; Unilever).

Our work on meeting the biological needs of captive apes has also led to significant projects with the Zoo Sector (*Chappell*: Drayton Manor Park) (*Thorpe and Chappell*: Twycross Zoo, Chester Zoo, Paignton Zoo, see impact case).

One area of industrial collaboration where we have had significant success has been through jointly funded DR projects. **Since 2014 we have had 26 iCASE awards and industrial PhDs** with businesses including both large international corporations (e.g. AstraZeneca, Syngenta, Unilever) and UK SMEs (e.g. Domainex, Kettle Produce).

*Birmingham Metabolomics Training Centre (BMTC)*
We provide training to industry in metabolomics technology through the BMTC. The centre provides introductory courses for researchers new to metabolomics, through advanced hands-on learning opportunities. Between 2015 and 2020 BMTC has operated four face-to-face courses (typically operated twice each year and of 2-3 days length) and two online courses (typically operated twice per year and of 3-4 weeks length) as well as providing a MOOC. This activity has provided training that has yielded >£200K in registration fees from:

- 477 trainees face-to-face and 11,100 trainees through the MOOC;
- Scientists from 54 countries and 240 different organisations.

### 4.2 Society

We believe that the expertise of our staff should have a central place in benefiting wider society. We encourage engagement at all levels including direct engagement through the media and indirect through engagement with third sector organisations and policy.

*Media*
We are actively involved in public engagement, across a wide range of media. Our staff have featured on BBC radio and TV news and current affairs, ITV, and Channel 4. *Chappell* is an external member of the BBC Worldwide Editorial Review Board for BBC Wildlife magazine. *Reynolds* has made several appearances on TV (BBC) and radio (World Service) talking about the effects of climate change in the South Atlantic on seabird diet and on species conservation in general. *Loman's* work to tackle the COVID-19 pandemic has been widely reported internationally in the world press, and through TV and radio interviews (several BBC and ITV appearances). *Orsini*'s work on evolution and climate change has been featured on multiple media outlets including the BBC and the New York Times. *Hayward's* research on insect biodiversity and climate change has been featured in over 20 UK and International media articles as well as appearances on TV (BBC). *Jackson's* research on tree diseases has featured in multiple TV and radio interviews. We are establishing long-term commitments to public engagement by staff, and by new generations of researchers encouraged by the work of our high-profile colleague *Alice Roberts* in her Professor of Public Engagement in Science role. Our staff participate in many public science festivals, including Brain Awareness Week, the British Science Festival, ESRC Festival of Science and Big Bang festivals, and the Pint of Science and Café Scientifique. UoA5 organises quarterly "Meet the expert" events at Birmingham Thinktank (science museum), where staff and PhD students present displays and demonstrations on a research topic to a large audience of the general public.

*Third Sector: non-governmental and non-profit-making organisations*
We provide support to third sector organisations to maximise our impact on society. Our staff have leadership and advisory positions in such organisations: *Bunce* was Research Director between 2012-15 at Leukaemia and Lymphoma Research (subsequently Bloodwise and now Blood Cancer UK); *Colbourne* leads the Environmental Care Consortium (ECC), a partnership of over 100 international science, legal and public health experts and students that confronts the global health and justice problems caused by pollution (environmentcareconsortium.org); *Chappell* and *Thorpe* have worked with two global NGOs (Orangutan Veterinary Advisory Group and Pan African Sanctuary Alliance) to promote adoption of evidence-based management of apes for both life-long sanctuary care and for rehabilitation and release. *Chappell* and *Thorpe* have also built partnerships with the major chimpanzee (Ape Action Africa; Chimpfunshi) and orangutan (Bornean Orangutan Survival Foundation; Sumatran Orangutan Conservation Programme) conservation organisations (funded by grants from NERC and the ARCUS Foundation).

### 4.3 Public Policy

Members of UoA5 have been actively influencing policy at both national and international levels. Prior to 2014 the activities of the members of UoA5 in this arena had been minimal. Over the last five years we have enhanced work in this area including advice to Governments leading to significant and sustained success.

*Dafforn* was (0.6FTE) CSA and Chief Entrepreneur at the Department of Business Energy and Industrial Strategy and was responsible for leading policy developments on Synthetic Biology and Student Entrepreneurship (delivered to the Prime Minister), and Entrepreneurship environment in England (part of the Government's Industrial Strategy).

*May* is currently (0.6FTE) CSA to the Food Standards Agency. His role gives him direct responsibility over research pertaining to UK food safety and is a central part of science advice to the Government Chief Scientific Advisor and DEFRA and Department of Health and Social Care Ministers. He works in conjunction with 1200 full-time staff with a budget of around £100M per annum.

Our strengths in genetics (plant and pathogen) are reflected in *Loman*'s position on the Public Health England Whole Genome Sequencing Group and National Sequencing Strategy Advisory Group, while *Maxted* is chair of the IUCN SSC Crop Wild Relative Specialist Group and DEFRA UK Plant Genetic Resources Group. *Lund* sits on the DEFRA Advisory Committee on Releases to the Environment (ACRE) and the HSE Scientific Advisory Committee on Genetic Manipulation.

In line with our research strength in plant sciences and food security, *Foyer* was a panel member of the National Centre for Universities and Business Food Economy Task Force and *Jackson* was a senior editor for the DEFRA-funded Action Oak Knowledge Review to synthesise current knowledge, identify research gaps and provide the foundations for future research strategy to study one of the UK's most important tree species.

**4.4 Enabling of interdisciplinary research**

Interdisciplinary research is a key focus for UoA5 since 2014 and into the future. To enable this activity, we promote a barrier-free working environment encouraging our staff to engage in projects across the university. Our Doctoral Training Programmes are all multidisciplinary and provide a basis for initiating cross-disciplinary research programmes. Growing these projects is further facilitated by University support through the Institute of Advanced Studies [REF5a, 2.3.2], Institute of Global Innovation [REF5a, 2.3.3], and the Development and Alumni Relations Office [REF5a, 4.1]. These provide targeted funding (to support networking, meetings, and interscholastic visits) as well as supporting large scale interdisciplinary grant applications. Our involvement in interdisciplinary and interscholastic DR training programmes (see section 1.4) ensures the concept of interdisciplinary working is at the heart of the training of our DRs.

An exemplar of this approach is BIFoR, which was established in 2013 as an interdisciplinary centre bringing together UoAs 5, 7 and 14 to create a step-change in UK forest research.

BIFoR has a significantly wider remit than managing the FACE experiment, driving interdisciplinary work considering all aspects of forests and forest management. Projects work across UoA7 and UoA14 as evidenced by the £1.04 m Forest Edge initiative providing Leverhulme income to 20 PhDs working between the humanities, physical and social sciences – seven of 15 studentships allocated to date have a UoA5 researcher as supervisor.

More recently this approach has led to a £19.3M grant from the EU for Precision Toxicology, which brings together scientists in UoA5 and UoA14 with social scientists in the University (UoA18) and 10 other institutions across Europe.

UoA5 is a member of the Midlands Integrative Biosciences Training Partnership, a partnership with four other Midlands Universities and the BBSRC; it has an ambitious vision to deliver innovative, world class research across the Life Sciences to boost the growing Bioeconomy in the Midlands and across the UK. PhD Studentship projects are focused in vital research areas such as Sustainable Agriculture and Food, Understanding the Rules of Life, Renewable Resources and Clean Growth, and Integrated Understanding of Health and use interdisciplinary and quantitative approaches to biology.

The University of Birmingham is a member of the national **Alan Turing Institute** [REF5a, 2.1.5], whose mission is to make advances in data science and artificial intelligence research to tackle the biggest challenges in science, society and the economy that ultimately benefit global society. Two UoA5 academics (*Loman* and *Orsini*) are Turing fellows, working on large scale interdisciplinary problems involving 'big data'. *Orsini's* long-term goal is to improve human health and wellbeing, prioritising pollutants for mitigation interventions. She is a key partner in the EU Precision Toxicology project involving 15 partner organisations in eight countries. *Loman* focuses on the development of state-of-the-art DNA/RNA sequencing technologies and bioinformatics methods to tackle major problems in public health and clinical microbiology e.g. major partner in virus genomics for surveillance (Ebola in Africa, with Public Health England and European Mobile Labs) and the COVID-19 Genomics Consortium (COG-UK) comprising 77 partners.

**4.5 Responsiveness to national and international priorities and initiatives**

Researchers in UoA5 respond quickly to acute global needs as evidenced by our response to the COVID-19 crisis. Members of our M&I and C&M themes quickly pivoted to provide support in instrumentation and personnel to the COVID-19 testing centres in the UK. To enable COVID-19 work to be accelerated UoA5 prioritised access to the research facilities for all COVID-19 projects. Building on his work for other major epidemics such as Ebola and Zika, *Loman* was able to rapidly pivot his genomic epidemiology work to encompass COVID-19 and became an integral part of the global effort to track the spread of the virus and identify strains (see REF3).

Within a month of the beginning of lockdown, *Dafforn* convened an interdisciplinary COVID research group that included researchers from academia and industry across the UK to coordinate work on the protein aspects of the virus. The group has met regularly to share results and reagents and work amongst this group has yielded several research projects funded through the UKRI COVID rapid response grant scheme. *Dafforn* has worked with the NHS and Linear Diagnostics Ltd to develop a novel rapid RNA assay system and has been involved in the establishment a new Diagnostics spin-out, Luas Diagnostics Ltd. His experience of rapid assay development has led to an invitation for membership of the UKRI COVID rapid response grant scheme panel.

**4.6 Wider influence and esteem**

*Academic Leadership*
Members of UoA5 also put significant effort into supporting the national and international knowledge base. We have two Fellows of the Royal Society (*Busby*, *Besra)* who are actively involved in the UK's premier science academy. At a national science policy level *Dafforn* and *May* as Chief Scientific Advisors for Government Departments provide advocacy for their disciplines to the highest levels of Government. *Dafforn* also represents Biosciences on the MoD's highest science advisory board (DSEC).

Our staff also play prominent roles in funding panels being members of nine council committees across BBSRC, NERC, EPSRC and Newton. We also play prominent roles on international funding panels including membership of panels in EU, China, Ireland, Czech Republic, Denmark, and Finland.

Our staff are also part of the management of large-scale national facilities including *Knowles* who is a member of the ISIS Neutron and Muon Facility User and Access Committee and Diamond Light Source User Committee Member.

Our staff hold positions on **> 20 editorial boards**. These include a number of highly prestigious journals including PNAS (*Thorpe*); Nature Communications (*Sanchez-Moran)*; Journal of Cell Science (*Heath*); Journal of the American Society for Mass Spectrometry (*Cooper*).

*Activities in learned societies*
Our staff also play roles in leading learned societies that represent leading biosciences disciplines. These include: *Foyer*, Secretary General, European Society of Plant Genetics; *Viant* President, International Metabolomics Society; *Busby,* Vice-Chair, Biochemical Society; *Ruth Roberts*, Board Member, Academy of Toxicological Sciences; *Jackson,* Vice President, British Society for Plant Pathology.

*Significant Awards during the REF period*
Our successes have been recognised in awards and honours for our staff since 2014:

- Fellowship of the Royal Society (FRS) (*Besra*) in 2019, meaning UoA5 now hosts two research active FRS (*Besra* and *Busby*) and one emeritus FRS (*Michell*)
- Royal Society of Chemistry Jeremy Knowles Medal/Award (*Besra*)
- Society of Toxicology Founders Award for Outstanding Leadership (*Ruth Roberts*)
- Wolfson Research Merit Award (*May*)
- Biochemical Society Colworth Medal (*Grainger*)
- Rank Prize New Lecturer awards (*Borrill* and *Luna Diez*)
- EMBO Young Investigator award (*Lovering)*
- Society for Experimental Biology Presidents medal (*Gibbs*)
- The New Phytologist Tansley Medal (*Borrill*)
- Royal Society David Attenborough Award (*Alice Roberts*)

**Concluding remarks**
We have invested heavily in people, infrastructure, and facilities to create a vibrant and supportive environment for biological sciences research. From this, we have secured substantial investment from government, industry, charity, and philanthropic donations, which allows us to address some of the most complicated, intriguing, critical and urgent scientific issues in the world. We demonstrate that our management approach and processes allow for our diverse staff to use these opportunities and thrive in our collegial and dynamic unit. As a result, we are delivering high impact scientific outputs which translate into crucially important changes that benefit our economy and society, and those of countries across the world. We aspire to be amongst the top biological science units in the UK and to get there, we will now focus on enhancing our inclusive research culture and using technology to drive new discoveries that generate impact. Importantly, our ambition is matched by our enthusiasm and dedication to be successful because we know that we are delivering research that is valued, and that we will continue to do so for future generations.