Institution: University of Leicester

Unit of Assessment: UoA5 Biological Sciences

1. Unit context and structure, research and impact strategy

The University of Leicester (UoL) has a long tradition of excellence over a broad spectrum of Biological Sciences research, reflected in the variety of organisms studied—from bacteriophage to barley, and from *Mycobacteria* to man—and the scale of questions addressed, from the molecular structure and function of transcriptional machinery to the genetic histories of human populations. Our researchers use a wide range of model organisms, including yeast, *Drosophila*, mouse and *Arabidopsis*, and have access to cutting-edge core facilities, including mass spectrometry, next-generation sequencing, multi-modal fluorescence imaging and cryo-electron microscopy. Cross-disciplinary projects are actively embraced leading to collaborations between biological and clinical researchers in Leicester that exploit fundamental discoveries to develop translational opportunities, and with physical and social scientists, as well as commercial and public partners, that make the most of strengths in atmospheric science and public health. Our research has had major impacts from the use of NMR structural biology to develop therapeutic antibodies (Impact Case Study 1 [**ICS1**]), to interdisciplinary teamwork (including ancient DNA analysis) that led to identification of the remains of the lost King of England and eponymous anti-hero of a Shakespeare play, Richard III (**ICS4**).

UoA5 comprises 63 research-active PIs (60.4 FTE) and their teams within the College of Life Sciences, organised into four interlinked research groupings (*Figure 1*) that represent long-term areas of strength, and facilitate collegiality, communication and collaboration; the **Structural & Chemical Biology** and **Microbiology & Infectious Disease** groups in particular have benefited from recent targeted institutional investment. Over the REF period there have been ten new PI appointments, linked to strategic priorities.

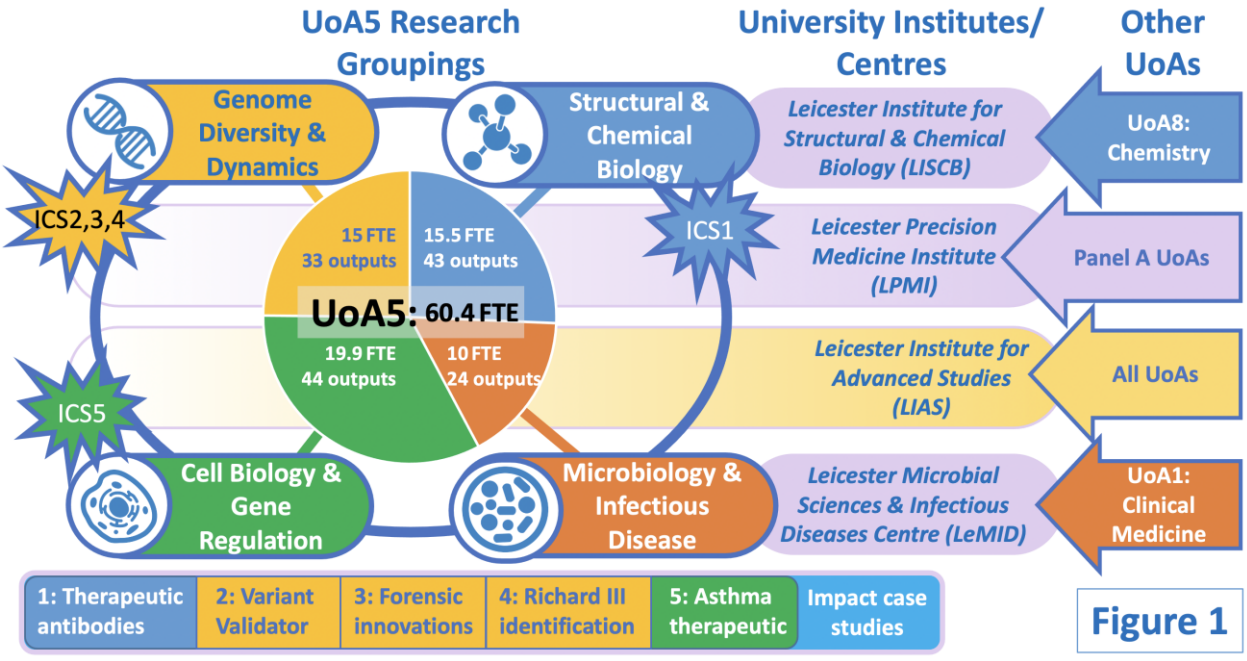

Figure 1

Since 2014 we have built on our research strengths, publishing over 1000 papers (20 per FTE) garnering 22,000 citations (20 per paper; mean field-weighted citation impact [FWCI] 1.75), and bringing in £58.3M of research income. Highlights of our research achievements include:

- A £4.3M grant (2017; MRC and regional partners), leveraged by strategic investment in new institutes, to establish a state-of-the-art Regional Cryo-Electron Microscopy Facility, and one of only six Cryo-EM locations UK-wide;

- Long-standing excellence in single-molecule approaches to gene expression, leading to a 2019 £3.7M BBSRC sLoLa award (2019) to investigate how RNA-binding proteins control splice site selection;

- Interdisciplinary collaboration between genetics and criminology empowering victims of sexual violence to collect forensic DNA evidence, supported by strategic internal seed-corn funding, and winning THE Award for Best Research Project in Social Science, Arts & Humanities (2018).

Research and impact strategies

Our Unit's overarching strategy is to provide an environment (including expertise, infrastructure, collegiality and mentorship of our people) that allows our researchers to identify the key biological questions, to pursue the most exciting ideas, to produce the most excellent outputs and impact, and to provide the best training for the next generation of scientists. This approach underpins the progress made during the current REF period, and the strategy going forward to the next. These aims have been facilitated by a 5-year **Wellcome Trust Institutional Strategic Support Fund** (**WTISSF**) award (£1.5M, matched by the University; 2017-22; one of 30 in the UK) led by our Dean of Research (**Fry**), entitled *Crossing discipline, ethnic and social boundaries to promote health*, which explicitly drives institutional culture change, and which the Wellcome Trust commended as 'one of the best in our ISSF scheme'.

• To support key **areas of excellence** the University invested in five research institutes in 2016, following a competitive process. The **Leicester Institute of Structural and Chemical Biology** (**LISCB**; director, **Schwabe**) includes sixteen UoA5 PIs, together with six PIs returned within UoA8, Chemistry. Meanwhile, many of our PIs with interests in human health (along with colleagues in UoAs 1, 2 and 4) belong to the **Leicester Precision Medicine Institute** (**LPMI**; co-director, **Jones**). This investment included new posts, facilities and project pump-priming, and has leveraged substantial research and impact success, described further below.

• **Emerging areas** have been nurtured by smaller-scale seed-corn funding. University 'Tiger Teams' accomplish specific short-term innovative projects, while interdisciplinary Networks are supported longer-term and more generously to allow relationships among researchers to mature. Successful Networks graduate to Research Centres with more substantial support, as has been the case for our **Microbiology & Infectious Disease** grouping of ten PIs, who have established the Leicester Microbial Sciences and Infectious Diseases Research Centre (**LeMID**). All these schemes are quality-controlled by internal and external peer review.

• **Achievement of impact** has been driven and incentivised by flexible internal funding schemes offering between £5k and £25k per round: the *Prospects* fund encourages researchers to be more entrepreneurial, and to exploit their research to generate public benefit; the *Proof of Concept* fund drives projects with commercial potential to achieve key milestones; the *Impact*

Development fund supports the collection of evidence of impact. Alongside these schemes there has been institutional investment in Public Engagement (PE), including the appointment of a Professor of PE (**King**), and a PE Manager (Marie Nugent), funded through our WTISSF. The Unit has hosted Chris Finnis, an innovator with 25-years' experience in the biopharmaceutical industry who was awarded a Royal Society Entrepreneur in Residence Fellowship (2018-20) to inspire entrepreneurship among staff and students. Since 2014 the Unit has benefited from translational funding from two MRC awards, receiving £65k of *Proximity to Discovery*, and £1.65M of *Confidence in Concept* funding.

• Leicester Drug Discovery and Diagnostics (LD3; within LPMI) supports **translational research**, providing pump-priming funds from seven consecutive rounds of awards (£3.1M since 2014) from the Confidence In Concept scheme to accelerate development of therapies, diagnostic tests and devices. Current projects include the development of decoy proteins to bind and trap coronavirus, exploiting our new CryoEM facility (**Brindle**).

• **Interdisciplinarity** lies at the heart of the **Leicester Institute for Advanced Studies** (**LIAS**), which reaches across the whole institution to nurture interdisciplinary research and manages the Tiger Teams and Networks mentioned above. Our WTISSF program included a *Discipline Bridges* scheme that supported 12 projects, including *Virus Fear: Cultural Resistance to Biophage Therapy*, a collaboration between **Clokie** and Elizabeth Jones (School of Arts). The interdisciplinary nature of LISCB lies in bringing together biologists and chemists (e.g. **Millard**, **Schwabe**, **Cowley**, *Chem Commun* 2020; **Eperon**, *Nucleic Acids Res* 2018), while LeMID provides a space for microbiologists to join with clinicians fighting infections on the front line. Our impact case studies showcase our interdisciplinarity, particularly in the Richard III identification project (**ICS4**), which involved collaboration between historians, archaeologists, and clinical/basic scientists (**King**, *Nature Commun* 2014).

• Development of Research Institutes and other investment has allowed us to **recruit** outstanding new staff, including ten strategically appointed new academics, three facility managers and industry liaison staff. We have supported external applications from Early Career Researchers (ECRs), both via the WTISSF (24 Fellows University-wide, internal and external candidates; 7 within UoA5, including **Fox**, **Roversi**), and other schemes, including a Wellcome Trust Career Re-Entry Fellowship (**Tufarelli**). Several WTISSF Fellows have progressed to permanent academic posts here or elsewhere. **Development of ECRs** has been promoted by an cohort-based strategy that supports fellows (both WTISSF and others) to meet regularly and join forces in organising regional WTISSF symposia with other universities, in training, and in PE activities. All staff are supported in career development by annual **Personal Development Discussions** (**PDDs**) which form the basis for reviewing progress, and promotions.

• We have maintained high levels of **research income** by continuing to gain awards from traditional sources including UKRI, CEC, Wellcome Trust, CRUK, and BHF, and by exploiting other opportunities including philanthropic donations and grants from other charities. We have supported our staff to grow the international aspects of their work and seek funding from Global Challenges Research Fund (GCRF) schemes, via annual competitive £10k International Research Development awards. Unit successes have mirrored excellent institutional performance here, as recognised by top THE ranking (2020) for the impact of UoL's research on the UN Sustainable Development Goal of Life on Land (e.g. **Clokie**'s BBSRC Newton Grant [£524k] involving two Thai and two UK Universities; **Heslop-Harrison**'s Newton-Caldas award [£200k] to support sustainable agriculture in Colombia).

• As well as winning external infrastructure awards (e.g. BBSRC Alert 18, **Higgins**) we have invested in **facilities and infrastructure** through the **University Research Equipment & Infrastructure Fund**, a £2M annual competitive scheme supporting purchase of equipment and match-funding of bids to external funders, bringing £4.3M into the Unit over the REF period. This equates to 31% of available funds, though UoA5 represents just 17% of eligible STEM FTE.

• As described in our Institutional Environment Statement (IES, section 2.6) we are progressing towards an **open research environment**; this includes promoting the uptake of FigShare, in place at Leicester since 2018 as a repository where users can make all their research outputs available in a way that is citable, shareable and discoverable, adhering to the FAIR principles. In 2020 the College of Life Sciences FigShare saw a monthly average of >40K views and >28K downloads. Aided by WTISSF funds, we hosted a 2018 Wellcome Trust Open Research workshop, and Library funding is available to support Open Access publication. During the assessment period, 80% of our outputs were published open access, compared to the Russell Group average of 63% (SciVal).

• We have energetically promoted a culture of **research integrity**: Leicester is a signatory of the Concordat, and set up a Working Group (chair, **Jobling**) in 2014. This group established mechanisms for regular revision of our Research Code of Conduct, and disseminated online training on Research Integrity & Ethics (via Epigeum modules)—mandatory for PGR students and available for all staff engaged in research.

• The University is a signatory of the **Concordat on Openness in Animal Research** in the UK, and our Pre-clinical Research Facility is proud of its Leader in Openness award for 2019-22 from *Understanding Animal Research*, following assessment including a public panel and peer review.

• We are committed to constantly improving our **research culture** to produce a vital, sustainable, inclusive and honest environment that brings the best out of all our researchers. We run well-attended and inclusive seminar series (since 2014, external and UoL speakers were 41% and 47% female respectively). We used WTISSF funds to support **equality, diversity and inclusion** (**EDI**) in research, to embed culture change in PE, and were invited by the Wellcome Trust to host the Midlands *Reimagining Research* Town Hall meeting (one of seven nationwide; Feb 2020). We signed the *Declaration on Research Assessment* (DORA) in 2018, affirming our commitment to the responsible and fair use of research metrics, and incorporated new recommendations on the use of metrics into our recruitment and promotions processes in 2020.

Research activities and achievements of the UoA

Our research and impact strategies have driven successes across the UoA:

1) **Structural & Chemical Biology** (**Carr**, **De Biasio**, **Dominguez**, **Eperon**, **Fox**, **Gooptu**, **Moody**, **O'Hare**, **Panne**, **Revyakin**, **Roversi**, **Schalch**, **Schmid**, **Schwabe**, **Vuister**, **Wallis**). Institutional investment in this grouping, as **LISCB** (including six PIs submitted to UoA8), has supported outstanding research and impact. The group abundantly achieved its REF2014 goals, winning a £4.3M grant (2017) to establish a state-of-the-art Regional Cryo-Electron Microscopy Facility, and ~£1M to upgrade its biological NMR Facility. A further goal was to expand translational structural biology, exemplified by a mature partnership with UCB and LifeArc to develop therapeutic antibodies (**ICS1**; **Carr**).

A core aim is to understand the **structures and mechanisms of macromolecular complexes** playing key roles in biological processes, including the regulation of post-translational modifications of chromatin, the selection of alternative pre-mRNA splicing, DNA replication, apoptosis, complement activation and ion channel formation. A second aim is to leverage fundamental discoveries to aid **structure-based drug discovery and design**; these include collaborations with chemists embedded within LISCB – e.g. developing PROTACs (Proteolysis Targeting Chimeras) to knock down specific proteins, including large gene-regulatory complexes (Hodgkinson, UoA8). **Single-molecule techniques** are used to investigate biological processes including transcription initiation and splicing complex assembly (**Eperon**, *Nucleic Acids Res* 2018). These dynamic approaches reveal the stoichiometry of protein assemblies, complementing the static views provided by other LISCB methodologies. **Over the next 5 years,** LISCB will use its expertise and facilities to further catalyse the development of research impacting human health, by building on partnerships with respiratory and cardiovascular researchers within the **Leicester Biomedical Research Centre** (BRC**)** and cancer researchers within the **CRUK Experimental Cancer Medicine Centre** (ECMC).

***Research highlights include*:** Ground-breaking structures of protein complexes regulating acetylation of histones to modulate gene expression (e.g. **Panne**, *Nature Chem Biol* 2018 and *Molecular Cell* 2017); First structure of a key protein for reverse cholesterol transport (**Schwabe**, *Cell* 2018); Structures of STAR proteins controlling splice-site selection (**Dominguez**, *Nature Commun* 2017); Mechanism of heme peroxidase via neutron cryo-crystallography (**Moody**, *Science* 2014 and *Nature Commun* 2018); Structure of the DNA polymerase delta holoenzyme (**De Biasio**, *Nature Commun* 2020); Dynamics of the transcription cycle via single-molecule analysis (**Revyakin**, *eLife* 2014; *Genes Devel* 2016).

2) **Microbiology & Infectious Disease** (**Bayliss**, **Clokie**, **Galyov**, **Ketley**, **Millard**, **Morrissey**, **Mukamolova**, **Oggioni**, **Pashley**, **Yesilkaya**). Institutional investment nurtured this research grouping, in the form of **LeMID**, the **Leicester Microbial Sciences & Infectious Diseases Centre**, established in 2017 (including six clinically-focused PIs in UoA1). It integrates microbial and infectious disease research across UoL and the NHS Trust, to drive basic, clinical, and translational research, and to promote enterprise in drug development, and diagnostic & treatment protocols. Aims are to understand transmission and pathogenicity of human and animal pathogens, including the role of host immunity and the environment, and to develop novel interventions and diagnostics, including innovative use of bacteriophages.

A major research theme is **host-microbe interactions and pathogen transmission**. This includes understanding host immunity to define interventions for infection prevention and vaccine optimisation; genomic analysis of hosts and microbes to define markers for host susceptibility, severity of infection, or success of treatment or prevention systems; and mathematical modelling of infection dynamics (**Bayliss**) and host-pathogen interactions. There is particular strength in studying *Mycobacterium tuberculosis* (**O'Hare**; **Mukamolova**) and *S. pneumoniae*, (**Morrissey**; **Oggioni**; **Yesilkaya**) including the role of bacterial physiology and genetics in disease, and the investigation of environmental effects. Another key theme is understanding the **ecology and molecular biology of bacteriophages** (**Millard**; **Clokie**), both in bacterial pathogens and environmentally important bacteria. Projects include isolating phages targeting *Borrelia*, the causative agent of Lyme disease (Phelix-funded; £470k), and developing phages to treat respiratory infections (*Pseudomonas*, *Burkholderia* and *Haemophilus*), as well as *Salmonella* (Innovate UK/BBSRC-funded; £105k). **Over the next 5 years** this grouping will strengthen its local and national clinical links, build impact in the area of phage therapies, and

work in interdisciplinary partnerships to investigate the influence of environmental change, including pollution, on bacterial behaviour and infection.

***Research highlights*:** Demonstration that pneumococcal virulence is regulated by a random six-phase switch influencing genome-wide epigenetic changes, including collaboration with UoL mathematicians (**Oggioni**, *Nature Commun* 2014); Interdisciplinary work with the Leicester Centre for Environmental Health and Sustainability demonstrating that air pollution impacts bacterial behaviour and potentiates infection (**Ketley**, *Env Microbiol* 2017); Identification of a set of phages targeting *Clostridium difficile*, currently being developed as therapeutic agents (**Millard**, *Antibiotics* 2018); industry-funded by AmpliPhi; £198k).

3) **Cell Biology and Gene Regulation** (**Amrani**, **Brindle**, **Challiss**, **Chen**, **Cowley**, **Fry**, **Goodall**, **Jones**, **Kyriacou**, **Macip**, **Mahaut-Smith**, **Mitcheson**, **Pullar**, **Rufini**, **Shackleton**, **Storey**, **Tanaka**, **Twell**, **Webb**, **Willets**, **Ye**). This grouping investigates molecular mechanisms of cellular regulation including gene expression, the cytoskeleton, ion channels, protein kinases and cell division. It includes researchers in functional genomics, studying genes highlighted in genome-wide association studies that play key roles in pathways affecting cardiovascular and respiratory disease (e.g. **Jones***, Circulation* 2019; **Chen**, *PLoS Genet* 2016). Long-standing research on circadian biology links to neurobiologists submitted within UoA4 and led to award of two successive EU-funded international doctoral programmes, **INSECTime** (2014-18; **Kyriacou**; €4M) and **CINCHRON** (2018-22; **Kyriacou**; €4M). Much of this research exploits excellent core advanced imaging facilities, is of pharmaceutical interest, and aligns with the strategic priorities of LISCB and LPMI. **Over the next 5 years**, this grouping will strengthen its collaborations with Leicester's cardiovascular and respiratory scientists and clinicians, and build on long-term strengths by investigating the interactions between circadian biology and environmental change.

***Research highlights*:** Role of a long noncoding RNA in mitigating atherosclerosis by regulating an actin-binding protein (**Chen**, *J Clin Invest* 2019); Pathogenicity of muscular dystrophy-associated variants explained by their disruption of nuclear-cytoskeletal connections and myonuclear organisation (**Shackleton**, *PLoS Genet* 2014); Establishing heme as a potassium channel regulator (**Storey**, *PNAS* 2017); Roles of transcriptional repressors in male germ-cell division and sperm viability in *Arabidopsis* (**Twell**, *Plant Cell* 2014), and of transcription factors in mouse spermatogenesis (**Rufini**, *PNAS* 2014); Importance of the chromatin modifiers Histone deacetylase 1 and 2 for accurate cell division and pluripotency of embryonic stem cells (**Cowley**, *PNAS* 2014).

4) **Genome Diversity & Dynamics** (**Beleza**, **Codd**, **Dalgleish**, **Dubrova**, **Guttery**, **Heslop-Harrison**, **Higgins**, **Hollox**, **Jobling**, **King**, **Louis**, **Mallon**, **May**, **Royle**, **Talbot**, **Tufarelli**). This grouping is united by an interest in the sequence variation within genomes, from fungi to plants and animals (including humans), how this variation arises, and its phenotypic and pathological consequences. Research into the genetic diversity of yeasts, as natural variation and in fine-grained quantitative analysis of complex traits in crosses, contributed to the EU-funded YEASTDOC doctoral programme (co-director **Louis**). Research in higher plants addresses genome sequences, and the regulation of recombination, important in diversity of crops including wheat and barley, supporting collaborations with crop-breeding companies (e.g. KWS UK Ltd., **Higgins** iCASE). Another major theme is the analysis of human somatic and germline genetic variation influencing cancer risk, including factors affecting telomere stability, and the influence of telomere length on health (£2M MRC-funded UK Biobank study; **Codd** with Samani, UoA1). Analysis of normal human genetic variation has illuminated human phenotypes including pigmentation (**Beleza**) and dietary adaptation (**Hollox**), and population processes such as

migration and sex-biased admixture. Studying genetic diversity in both human and animal populations finds translational applications in forensics. This is embodied in the Alec Jeffreys Forensic Genomics Unit and includes work that underlies two impact case studies (**ICS3, ICS4**). **Over the next 5 years** this grouping will build on its work on human genome variation and disease susceptibility, including collaborations with members of LPMI, and use its work on model and non-model organisms as a platform for innovative funding applications in the area of global challenges and industrial partnerships.

***Research highlights include*:** Characterisation of functional genetic variation from natural yeast genomes (**Louis**, *Mol Biol Evol* 2014); Demonstration that variants near *TERT* and *TERC* influencing telomere length are associated with high-grade glioma risk (**Codd**, *Nature Genet* 2014); Interdisciplinary work identifying the remains of King Richard III, garnering global attention (**King**, *Nature Commun* 2014; **ICS4**); Work marrying basic circadian biology (**Kyriacou**) with patient-centred work on radiotoxicity (**Talbot**) showing that variants in circadian rhythm genes influence side-effects in breast cancer radiotherapy (*Johnson 2019* **Clin Oncol**).

In conclusion: We will consolidate and extend the links between fundamental research in Biological Sciences and Leicester's translational and clinical strengths in cancer, cardiovascular and respiratory science, and infectious disease. We will build on our strong interdisciplinary connections with the physical and social sciences, and our successes in meeting global challenges in food security, health, and a secure world, and in partnering across this broad range with industry. We will continue to support innovation and collaboration among established investigators, and to nurture the next generation, on a secure foundation of improving equipment and infrastructure.

2. People

Staffing strategy and staff development

The University aims to attract the very best Biological Sciences researchers and to nurture their development at every stage of their careers. Within the Unit, the overall strategy is to: (i) recruit academic staff who have the highest potential to achieve excellence in research and strengthen priority areas; and (ii) support new and existing staff to realise their maximum potential, through individual mentoring, incentivisation, training and team working. We attract new staff and retain them by highlighting our focused research strengths, developing the quality of our physical environment and research culture, investing in facilities and research centres, and embracing EDI.

Recruitment strategy

In recruiting staff, the Unit has attracted established and internationally recognised researchers to strengthen specific areas, mid-career investigators to bring new skills, and ECRs to support career development using our WTISSF ECR scheme and other sources (e.g. Royal Society, WT, Daphne Jackson).

• ***Strengthening specific research areas***: Major institutional investment has occurred in our Structural and Chemical Biology grouping driven by LISCB. **Panne**, who studies the structural biology of signal transduction and epigenetic gene regulation, was recruited from EMBL Grenoble, while **Schalch** brought his research on the 3D organisation of chromatin from the University of Geneva. Recruited from Elettra-Sincrotrone Trieste, **De Biasio** brought expertise in

the architecture and function of DNA replication and repair machinery. The excellent international connections of these investigators provide a platform to facilitate collaborations that support future impact as well as research. Other strategic appointments include **Millard**, within our Microbiology and Infectious Disease grouping, recruited from Warwick as a lecturer (now Associate Professor). He brings important expertise in bioinformatics and metagenomics, and his research programme strengthens the phage biology theme. **Chen** joined us in 2020, adding strength to the behavioural genetics research of **Kyriacou** and other colleagues returned in UoA4 (Giorgini, Rosato).

• ***Supporting ECRs as fellows***: The Structural and Chemical Biology grouping was enriched by recruitment of two Leicester WTISSF (2-year) fellows, **Fox** and **Roversi**, the latter recently being appointed to a permanent lectureship post. **Tufarelli** won a 4-year WT Career Re-entry Fellowship (£450k), sponsored and mentored by **Goodall** and UoA1 cancer researchers. She studies the mechanisms and implications of L1 element reactivation in colorectal cancer, linking basic cancer biology with clinical work on biomarkers.

• ***Recognising technicians***: UoL is a founding signatory (2017) of the Technician Commitment, a Science Council initiative. This recognises that technical staff are fundamental to university life, and provides a programme to increase the visibility of our technical workforce, to celebrate their excellence and to support career development. It includes a Technical Skills Placement Programme allowing technicians to develop new skills in other institutions, and the annual UK HE Technicians Summit, at which our own Lory Francescut won a prestigious Papin Technician prize (2019) for her work supporting PIs including **Mahaut-Smith**, **Storey**, **Mitcheson** and **Brindle**.

• ***Demographic staff profile***: Our submitted staff are 27% female (the same as REF2014), but our proportion of female professorial staff has increased from zero to 35%, reflecting a College-wide increase from 18 (2014) to 32 female professors (2020). Our PIs fall into the following age bands: 30-44 years: 19.4%; 45-60: 64.5%; >60: 16.1%; we recognise that this is top-heavy and are recruiting outstanding ECRs into areas of institutional investment and strength to ensure succession.

• ***EDI in recruitment and retention***: An equal, diverse and inclusive environment is key to attracting, recruiting, developing and retaining excellent staff. The recent Athena SWAN Silver Award to the College of Life Sciences, and previous awards to individual departments, demonstrate our commitment to improving our culture. 93% of female academic staff feel that our recruitment processes are fair. Leicester is a culturally diverse city (51% BAME) and we ensure that we monitor and reflect gender and ethnic diversity in all recruitment and publicity materials.

Staff development and retention

Development and progress are key to retaining staff and creating a vital and sustainable research culture. The Unit contains good examples of PIs whose careers have developed in Leicester thanks to supportive mentoring: **Bayliss** was a new RCUK Fellow in 2007, and in 2020 has become a Professor; **King** enrolled as a PhD student in 2000 and via post-doc and lecturer positions is now the University's first Professor of Public Engagement; **Guttery** did a PhD and post-doc at UoL, and in 2017 was appointed as Lecturer in Cancer Early Detection; **Codd** did her PhD with **Kyriacou** and progressed (2020) to Associate Professor in Cardiovascular Sciences. Such development and retention of excellent researchers illustrates the sustainability of our environment.

• ***Mentoring, probation, and appraisal***: Within the College of Life Sciences there is a well-established mentoring system, forming a central part of the University's implementation of the Concordat to Support the Career Development of Researchers, and Departmental and College Athena Swan action plans. Newly appointed academic staff have a mentor who facilitates professional growth by advising on research plans, development of grant applications and publications, and broader aspects of career development, including learning new skills, attending courses, promotion, engaging in cross-disciplinary research, enterprise, and impact. During their three-year probationary period they receive clear guidance on the expectations for their duties, responsibilities and level of performance, and regular feedback. Appraisal is managed via annual PDDs linked to career progression, which is guided by the Career Map recognising contributions to citizenship and leadership as well as to research, teaching and enterprise. The PDD emphasises agreed goals and identifies the support needed to achieve SMART objectives, ensuring that all staff receive advice on how to succeed as researchers and on career progression and promotion. It provides an opportunity to discuss promotion planning, and to examine any barriers that might exist for particular individuals. 37% of our submitted academic staff have been promoted during the REF period.

• ***Training, networking, and professional development*** opportunities are available to all PIs, both within the institution and externally (IES, 3.2). Examples are the *Aurora* programme aimed at female leaders (University-supported), and *BAME Leadership* courses (WTISSF-supported). **Morrissey**, who joined UoL in 2000 as a lecturer and is now a Professor and co-director of LeMID, benefited from the University's *Future Leaders* course.

• ***Concordat to Support the Career Development of Researchers***: In 2020 the University retained its HR Excellence in Research Award following the eight-year review. This recognises the implementation of the principles of the Concordat, and its retention demonstrates our long-term commitment to these. Implementation of Concordat strategy is overseen by the ECR and Research Staff Career Enhancement sub-committee and supported by the Post-Doctoral Research Staff Association.

Research Students

Postgraduate Research Students (PGRs) are an essential part of our community, and we are committed to ensuring they receive excellent support and training. The University's Doctoral College launched in 2017 to replace the previous Graduate School, with a wider remit extending across the full early-stage career journey to promote seamless transition between stages. It covers 2200 PGRs, 439 research staff and 932 early career academic staff, and aims to develop rigorous and intrepid researchers, with world-class capabilities in the leadership, execution and communication of research, prepared for both academic and non-academic careers. The Doctoral College is overseen by the Postgraduate Research Policy Committee, which promotes best practice in all aspects of the University's PGR provision.

PGR positions are advertised via open-access online platforms including FindAPhD.com. Applicants must be suitably qualified and hold a 2:1 or first-class UK Bachelor's degree, or equivalent, in a relevant discipline. Non-native English speakers may either have been educated in English or hold an IELTS score of ≥6.5. Specific multi-institutional DTPs have their own rigorous procedures for student selection. All applicants are formally interviewed before acceptance.

• ***Our PGR graduates***: A total of 340 PhDs graduated from UoA5 during this REF period (*Figure 2*). We are proud of the diversity of this cohort, which has an even gender split, and encompasses 47 nationalities (32% are British, of whom 27% are BAME—compared to UK average of 17% [HESA data 2017-18]). We support our international students via the English Language Training Unit, which provides pre-sessional training, allowing students to improve their skills before beginning their studies, and courses in English skills, academic writing, and giving research presentations throughout their PhD.

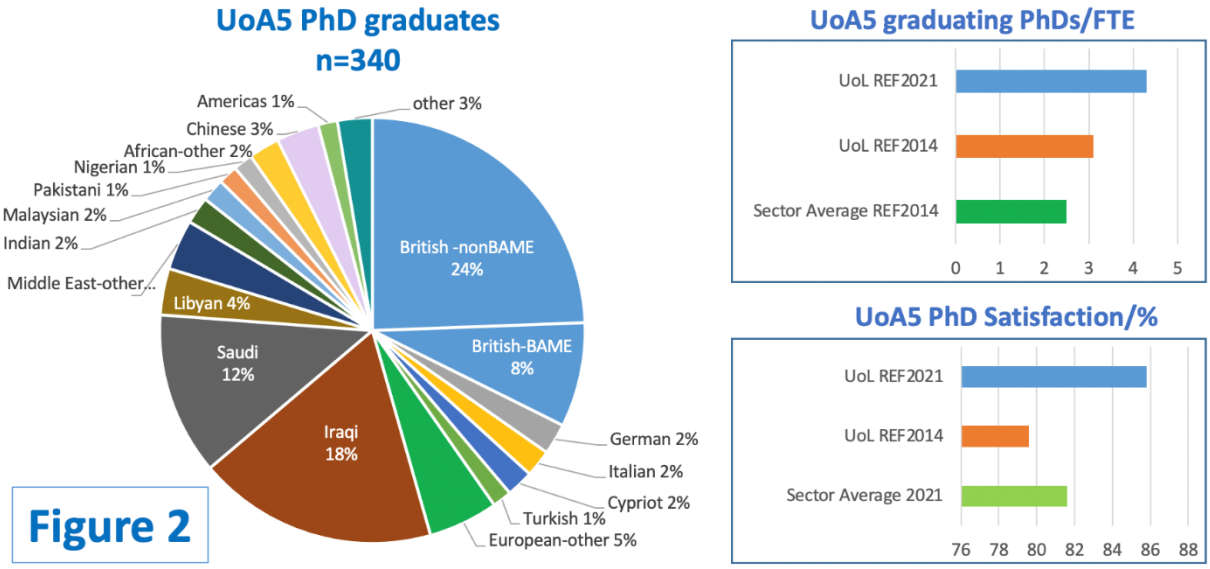

Figure 2

Students within UoA5 are supported by a rich range of DTPs from major funding bodies (all with matched university funding), institutionally supported positions, and studentships from overseas agencies and other sources:

• ***BBSRC*** (31 UoA5 graduates): the Midlands Integrative Biosciences Training Partnership (MIBTP) delivers innovative research training across the life sciences to boost the growing bioeconomy. Initially supported from 2015-19, the programme was renewed as MIBTP2020, including the Universities of Leicester, Warwick, Birmingham, Aston and Harper Adams (total £20M), supporting 52 x 4-yr studentships annually. The Unit's BBSRC-funded students currently include 9 iCASE awards (Section 4).

• ***MRC*** (20): IMPACT (Integrated Midlands Partnership for Biomedical Training; £3.5M) supports 14 students annually between the Universities of Leicester, Birmingham, and Nottingham. Research projects focus on the theme of Complex Disease, allowing students to benefit from a diverse range of projects and skills, stimulating them to perform innovative, world-leading research.

• ***NERC*** (2): the Central England NERC Training Alliance (CENTA) is a consortium of research-intensive Universities and institutes including Leicester, first funded in 2013, and renewed in 2019 (CENTA2; £4.9M; 24 students/year). The programme includes an Organisms theme, and UoA5 PhD students working on genomic imprinting in social insects (**Mallon**), and great-ape conservation genomics.

• ***Wellcome Trust*** (£5.15M; 8 students/year): the Genetic Epidemiology & Public Health Genomics Programme is a new (2020) DTP, allowing students to focus on key public health research needs, including improved healthcare through genetically-driven methods; ensuring equal representation of minority groups in research; and advancing the benefits of genomics for hard-to-reach and deprived communities. To broaden access, UoL provides fee waivers for up to 10 trainees from low-to-middle-income countries.

• ***EU*** Initial Training Networks (ITNs; 36 students total): UoA5 PIs are key players in the award of five ITNs, INSECTime (2014; **Kyriacou**; €4M), CINCHRON (Comparative INsect CHRONobiology; 2018; **Kyriacou**; €4M), YEASTDOC (Training Programme in Yeast Biotechnology; 2017; **Louis**; €3.1M); MEICOM (Meiotic Control of Recombination in Crops; 2018; **Higgins;** €3.1M); and NR-NET (Control of metabolic and inflammatory pathways by nuclear receptors; 2013; **Schwabe**; €4M). A sixth Leicester ITN, INTREPID Forensics (Interdisciplinary Training and Research Programme for Innovative Doctorates in Forensic Science; 2014; €2.9M) supported a UoA5 student during the REF period.

• ***Other UK funders***: studentships include funding from the Royal Society, HDR UK, British Lung Foundation, British Heart Foundation, and the local charity Hope against Cancer.

• ***Internal funding***: internal funds have supported 40 students in the current REF period for new PIs and to strengthen strategic areas; for example, LISCB and LPMI studentships are jointly funded by the College of Life Sciences.

• Remaining students are funded via a mix of **overseas government/university sponsorship** and **self-funded** studentships.

• **Monitoring and support of student progress** is overseen by the Doctoral College. The online system MyPGR (2019; replacing a previous system) is used to monitor and record formal monthly supervisory meetings, and objectives and milestones as the project proceeds. There is academic and pastoral support more locally in the form of Departmental Postgraduate Research tutors.

Each PGR student is initially registered for a one-year probation as an Advanced Postgraduate. All students have at least two supervisors, and an independent progress review panel (PRP) comprising two academics. Students and supervisors meet at least monthly and record their meetings through MyPGR. An early meeting introduces the student to their PRP, and provides a project viability check. After 9 months, the student submits a report including a literature review, meets their PRP and gives a seminar during one of the regular postgraduate research days. This is an important decision point where the PRP recommends either progression to a PhD degree, revision and resubmission of the research proposal, or termination of studies. Students must complete research within 3 years of registration and submit their thesis within 4 years. In REF2014, UoA5 had 3.1FTE completed PGRs/FTE over a 5-year period, compared to a sector average of 2.5/FTE. For the most recent 5-year period for REF2021 the figure is 4.3/FTE, demonstrating a clear increase (*Figure 2*). Overall satisfaction with their PhD course has improved from 79.6% (2015 PRES data) to 85.8% (2019), compared to a sector average of 81.6%.

• **PGR training**: DTPs have their own specialised training programmes, but all students benefit from a broad range of training delivered at Leicester and partner organisations. The programme is based on the skills and experience that UKRI expects PGRs to develop during their research

degree, guided by Vitae's Researcher Development Framework. Elements include: research ethics and integrity, research effectiveness (including literature searching, working with big data, visualising data, and using bibliographic software and FigShare), academic writing, quantitative methods (e.g. R, SPSS), designing and measuring impact, and media skills. Specific research training (based on a training needs analysis) is reviewed in supervisory meetings and annual reviews, and recorded using MyPGR.

Our UKRI-funded DTPs are collaborative with other institutions and industrial partners, and students benefit from cohort-based training and 'masterclasses', based at UoL or with a partner. iCASE students benefit from training with their industrial sponsors.
As well as drawing on their research training support grants to attend courses and conferences, PGR students are encouraged to join national and international scientific societies (e.g. Genetics Society; Biochemical Society), and apply for grants for training, research visits and conference attendance.

The Doctoral College provides excellent opportunities for PGR students to showcase their research, engage with the public, and network. These include Pint of Science and PubhD; Cafe Research; Three-minute thesis presentations; Doctoral inaugural lectures for prize-winning theses (e.g. Tunde Huszar (**Jobling**) won a prize, and contributed to work in **ICS3**); the annual Images of Research exhibition; and the Festival of Postgraduate Research, where a set of the University's best students, selected competitively, present their cutting-edge research to academics, employers, and the public. Our students regularly enter the national BBSRC Biotechnology YES competition, with UoA5-based teams winning in both 2014 and 2018.
The Careers Development office provides advice on career planning, preparing job applications and CVs, and personal development, as well as career events focused on particular subject areas within and outside academia, and advertises internships and work experience opportunities. The new WT-funded DTP provides flexible funding for up to a year post-PhD, to support students in their next career steps.

Recognising the disruption caused by the Covid-19 pandemic, UoL provided additional financial support for PGR students totalling £272k in funded extensions, fee waivers and hardship funds.

• **PGR integration into the research community**: Each PGR student is embedded within a research group, and participates in group meetings, journal clubs and public engagement events. They attend Departmental, College and University seminars, and over their PhD career give talks and posters at PGR research days which PIs and post-docs also attend.
The quality of our PGR cohort is reflected in excellent submitted REF outputs that include PhD students among their authors (34%; 17% first author). We are proud of student successes, e.g.:

• Cecilia Casadei (**Moody**: *Science* 2014 and *Nature Commun* 2016), was supported by an Institut Laue-Langevin (ILL) studentship and won a College prize and a place to present at the 65th Lindau Nobel Conference. She is now a PDRA at ETH, Zurich.

• Carika Weldon (**Dominguez**: *Nature Chem Biol* 2017 and *Nucleic Acids Res* 2018) gained a lectureship at De Montfort University and is now a scientist at the Wellcome Trust Centre for Human Genetics in Oxford. She created and leads the Bermuda Principles Foundation to promote science in her native country.

• Kerstie Johnson (**Talbot**) won the Frank Ellis Medal from the Royal College of Radiologists for Johnson *Clin Oncol* 2019, and is now a Consultant in Clinical Oncology at Nottingham University Hospitals.

Equality and Diversity

EDI is embedded in the University's Strategic Plan and is central to the vision of our VC, Nishan Canagarajah (appointed 2019). A University-wide culture of inclusion encompasses all aspects of our activity and business (IES, 3.1). EDI staff fora (e.g. BAME, LGBT, Disability, Women's, Senior Women's and World Faith Groups) welcome and include our staff, and a number of features of the institution make it an attractive place for a diverse workforce—these include HeforShe status (the UN's solidarity campaign for gender equality, involving only ten universities worldwide), Race Equality Charter signatory, Top 50 Stonewall employer, and University of Sanctuary award. In 2018, the University gained an Institutional Silver Athena SWAN award, followed by a successful application for Silver from the College of Life Sciences in 2020. There are Diversity Champions in every Department and regular EDI-focused seminars and workshops. There is transparent reporting of the institutional gender pay gap and a clear action plan to address this.

Three of our female professors (**Clokie**, **Goodall**, **King**) have featured as part of the University's Inspiring Women campaign, presenting strong female role models to students and staff. Both **Clokie** and **King** were 2019 guests on BBC Radio 4's *The Life Scientific*, discussing their careers and their research, and **Clokie** featured on the same station's *Infinite Monkey Cage* in 2018.

There is mandatory online training for all academic and post-doctoral staff in EDI and in Challenging Unconscious Bias; this must be refreshed every three years and is followed up at PDDs. Staff contributions to improving EDI are recognised and celebrated—the University's annual *Discovering Excellence Awards* includes one for equality champion.

Our WTISSF award provided a springboard to develop and apply EDI principles across its schemes that have been adopted elsewhere, e.g. by the new WT-funded DTP. These ensure transparent and fair processes that include: clear, consistent, published guidelines and processes for funding and recruitment decisions; consistent explicit consideration given to gender balance and where feasible BAME membership of all assessment, shortlisting and interview panels; and diversity monitoring of awards. Valuable input into our processes has come from the Leicester Centre for BME Health and criteria for all schemes are scrutinised to confirm adherence to our EDI principles. ECR fellowship candidates are scored in both shortlisting and at interview using detailed rubrics (to further safeguard against unconscious bias). We ensure all of our application deadlines and meetings are compatible with school term times. Applicants are invited to detail career breaks, or other relevant personal circumstances, in applying so that they can be taken account of in the selection process.

We strive for transparency in promotion procedures, which is helped by our PDD system. Workload models are adjusted to take account of fractional contracts.
The Unit benefits from a set of clear University-level policies, including:

• Flexible working: to support staff with care responsibilities, ill-health or disability, or who are engaged in further education or training, pursuing other interests or activities, or working towards retirement. This includes job sharing and compressed hours, working from home and tele-working.

• Maternity and adoption leave: meeting the statutory entitlement for staff to take 52 weeks leave regardless of gender or length of service. Research may suffer during such leave, so the University provides funded support for the duration: '*Having someone cover for my role while I was on maternity leave and having a period of handover when I returned really helped. They were so organised and dedicated to the role when I was off so I didn't return to a big mess!*' (Female researcher).

• Menopause transition: Leicester was the first university to launch a menopause policy (2017), and holds regular Menopause Cafés for informal conversation and support.

• Parental leave: entitling staff to take up to a total of 4 months' unpaid leave for children under the age of 5 or, in the case of a child under the age of 18 who is receiving disability living allowance, 18 weeks' unpaid leave.

• Dignity at Work code of practice: to ensure that all staff are treated with dignity irrespective of age, disability, gender or gender reassignment, marriage or civil partnership, race, religion or belief, sex, or sexual orientation.

• A zero-tolerance policy for bullying and harassment, victimisation of those who allege bullying and harassment in good faith, or the failure to support someone in making such a complaint.

• A Carer Conference/Travel fund to cover caring fees while attending conferences and study days.

• A back-to-work meeting for staff returning from periods of leave (including parental leave) held with their line manager to address how best to facilitate their return to work.

• Study leave entitlement, in which all staff can apply for one semester of leave every seventh semester. Requests are considered at departmental level to ensure consistency and fairness, and supported requests are forwarded to the College Study Leave Committee.

The University places great importance on staff wellbeing, providing information on dealing with work-related stress, managing mental health problems, and managing physical discomfort, back pain, sleep problems and sedentary working. Managers take steps to mitigate against workplace stress, and to liaise with staff experiencing stress to make reasonable adjustments to working environment and workload, and refer them for an occupational health assessment where necessary.

PGR student wellbeing is supported via the Student Health and Wellbeing Team, and Headspace, the mental health drop-in in the Students' Union, and by training students as Mental Health First Aiders and Wellbeing Champions to support their peers.

3. Income, infrastructure and facilities

Research Income

The Unit's research income over the REF period was £58.3M (£138k/FTE/year). Unsurprisingly, this mean value is lower in an all-in REF than for the selective REF2014 (£164k), but the trend is

upward. Funding came from a wide range of sources including UKRI (BBSRC, MRC, EPSRC, NERC), the European Commission, major charities (e.g. Wellcome Trust, BHF, CRUK, Leverhulme Trust), smaller charities (e.g. Hope Against Cancer, Asthma UK, Meningitis Research Foundation), and industry based in the UK and overseas.
Research staff are supported to generate high-quality grant applications via a range of mechanisms aiming to promote a sustainable and vital research environment:

• **Annual PDDs** include a discussion of grant applications during the past year and their outcomes, and agree future targets.

• Departments and Institutes support regular **grant development meetings** where PIs present ideas to colleagues for feedback and creative input. Regular targeted emails inform PIs about grant opportunities and deadlines.

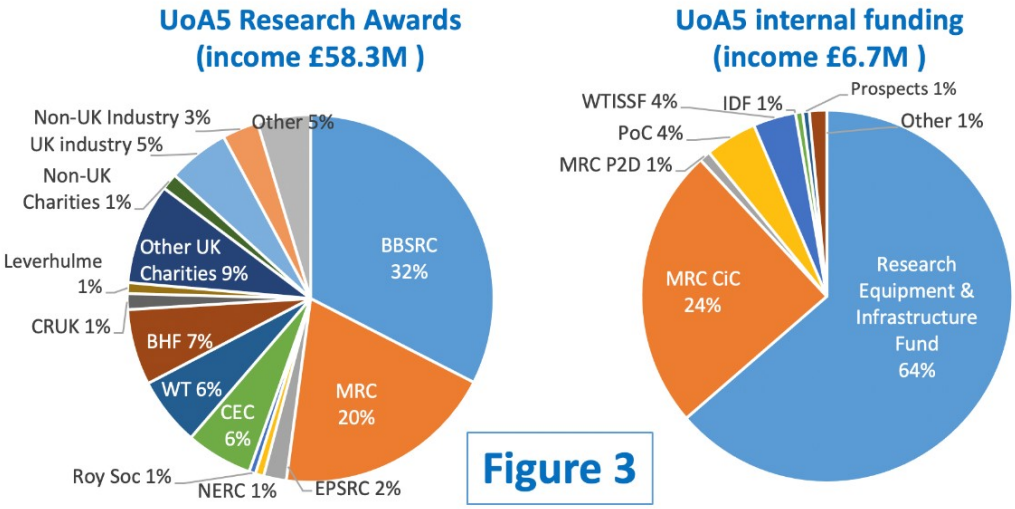

Figure 3

• The College Research & Enterprise Committee, chaired by the College Dean of Research (DoR, **Fry** 2014-2020), oversees strategy within the Unit and sets key performance indicators, including **targets for applications and awards,** reviewed annually. The DoR reports directly to both the College Leadership Team and institutional Research & Enterprise Committees.

• The institutional **Research & Enterprise Division** (**RED**) team (IES, 4.1) supports bids and sends regular alerts about funding opportunities to PIs.

• At University level, **key funder working groups** for each of the research councils, plus the Wellcome Trust, Leverhulme Trust, Innovate and NIHR, build relationships with funders, publicise funding schemes, review applications and provide mock interviews for fellowship candidates. Professional staff within RED support grant writing, costing, MTAs and collaboration agreements. GCRF grant-holders are brought together for networking sessions to share expertise, and this is disseminated to the wider community, with PIs supported via internal schemes to co-develop projects with international partners.

• Our WTISSF scheme leverages further grant income; for example, a WTISSF ECR fellow, **Roversi**, was supported in a successful WT Seed Award application, and another, Jo Purves, is now a researcher-coinvestigator on **Morrissey**'s £441k BBSRC award.

• As mentioned in Section 1, there are diverse internal funding sources (*Figure 3*), and funding to UoA5 over the REF period totalled £6.7M. Individual awards can be small sums, but they leverage collaborations, larger external awards, and impact. As examples:

• Interdisciplinary work to find novel solutions to collect evidence following sexual violence in low-resource environments began with a 2015 £10k Prospects award to **Jobling** and Lisa Smith (Criminology), leading to a publication and external £50k Humanitarian Innovation Fund grant. Kenya was suited to implementation, so a UoL International Research Development award (£9k; 2018) was used to bring an academic from Kenyatta University to Leicester, supporting Kenyan DNA sampling. The University Research Infrastructure Fund then allowed purchase (£177k) of a new ABI3500xl Genetic Analyzer, permitting high-resolution genotyping by a visiting Kenyan PhD student, thus establishing reference DNA profile databases to underpin Kenya's criminal justice system. This work contributed to a 2018 national THE award, a 2019 philanthropic award (£450k) from Ring of Peace, and an impact case study (**ICS3**).

• **Clokie** has used internal funds to pump-prime work to progress bacteriophage products from the laboratory bench to commercial applications in animal, human and plant health, together with industrial partners. Grants from our internal MRC Confidence in Concept scheme (£43k and £51k; 2016 and 2018) supported work on a novel phage-based diagnostic test for Lyme disease allowing a patent to be filed (2017) for a test currently undergoing a full commercial trial with a European diagnostic company. A 2017 Proof of Concept Fund Award of £15k to support a project on *Salmonella* phages led to a 2018 patent, and a £264k partnership with ABAgri, a multi-national subsidiary of Associated British Foods, to develop animal feed that contains phages to prevent *Salmonella* entering the human food chain. This vital work on phages will form the basis of an impact case in a future REF.

• Development of VariantValidator (**Dalgleish**), software that improves the accuracy and precision diagnosis of genetic disorders, benefited from three awards from our internal MRC Proximity to Discovery fund (total £12k), as well as a WTISSF fellowship to Peter Freeman (Freeman, *Hum Mutat* 2018) and forms the basis of an impact case study (**ICS2**).

The collegial approaches we have in place to support development of funding applications contribute to the vitality and sustainability of research income. Our growing income from commercial and international sources over the REF period demonstrates that the Unit is agile and flexible in its approach to seeking funding. The willingness of colleagues to engage in interdisciplinary working, nurtured by LIAS and institutional funding sources, also promises access to wider sources of support in the future.

Infrastructure and Facilities

The Unit benefits from high-quality clinical and basic infrastructure. Leicester Academic Health Partners embodies the close relationship between the University Hospitals of Leicester NHS Trust, Leicestershire Partnership NHS Trust and UoL. This harnesses our collective clinical and academic excellence to accelerate the transmission of cutting-edge research into healthcare innovations to improve the health and well-being of the people of Leicester, Leicestershire and Rutland (LLR). The prestigious award of an **NIHR Biomedical Research Centre** (BRC), with an £11.6M (2017) grant supporting Cardiovascular, Respiratory and Lifestyle themes in a partnership between UoL, Leicester's Hospitals, and Loughborough University, has strengthened links between lab and clinic. As part of the BRC, the Institute for Lung Health (including **Amrani**, **Carr**, **Challiss**, **Gooptu**, **Hollox**, **Morrissey**, **Mukamolova**, **Oggioni**, **O'Hare**, **Pashley**, **Wallis**, **Yesilkaya**) underpins **ICS5** (Andrew Wardlaw), which describes the

UoL/GSK collaboration resulting in the development, licensing and widespread use of a first-in-kind monoclonal antibody, mepolizumab (Nucala™), which prevents severe asthma exacerbations.

The £42M **George Davies Centre** (2016), the UK's largest non-residential Passivhaus building, provided a new home for the Medical School and non-lab-based researchers and allowed a reorganisation of space. Investment in bioinformatics has continued with the ongoing activity of the **Bioinformatics and Biostatistics Support Hub** (BBASH), now part of a higher-level alliance BINERI (Biomedical Informatics Network for Education, Research and Industry), which unifies training, big data analysis, biobanking, ethics, governance, and information technology. UoL now co-leads the Midlands Substantive Site for the **Health Data Research UK** Institute.

As described in Section 1, external funding and internal investment allowed the creation of LISCB; its world-class facilities are supported by specialised and skilled managers and include:

• **Midlands Regional Cryo Electron Microscopy facility**: FEI Titan Krios with K3 and Falcon 3 cameras, Phase Plate; full-time facility manager (Christos Savva). The facility, one of only six cryoEM locations in the UK, has already brought in >£1.7M of research grants that will use this facility, and international (Spain; USA) and industrial (e.g. Sanofi, Evotec, Casma, Vernalis, Omass Theurapeutics) users. Excellent supported research outputs include: **Cowley**, *Nature Commun* 2020; Lancey *Nature Commun* 2020; Song *Cell Rep* 2020.

• **High Performance Image Processing cluster:** 6 x Compute nodes each with 4 GPUs and 20 CPU cores; 4 x Management nodes; 6 x Storage nodes with 800TB storage as a distributed file system (57Gb Infiniband); full-time facility manager (TJ Ragan); Skinner, *J Biomol NMR* 2016.

• **NMR Facility:** 800MHz spectrometer with liquid state cryo-probe and solid-state probe; Two 600MHz spectrometers with cryo-probes; 500MHz spectrometer; facility manager Fred Muskett. This facility is crucial to a long-standing industrial partnership between **Carr**, UCB and LifeArc underpinning an impact case study (**ICS1**) and outputs including **Carr**, *PNAS* 2020.

• **X-ray Facility:** 5 x crystallisation robots; dedicated crystallisation rooms; in-house X-ray set Rigaku 007HF with CCD detector. **Schwabe** *Cell* 2018 etc.

• **Biophysics Facility:** CD machine**;** 2 x ITC machines**;** Octet**;** Caliper**;** Stop-Flow: 0.6FTE Facility manager (Jaswir Basran). Outputs include: **Moody**, *Science* 2014; Kwon *Nature Commun* 2016; **Moody**, **Storey**, *Nature Commun* 2018; Freeman *PNAS* 2019.

The Unit benefits from additional facilities and infrastructure under the umbrella of Core Biotechnology Services (CBS):

• The **Advanced Imaging Facility**, managed full-time by a specialist (Kees Straatman), offers confocal and conventional fluorescence microscopes and image analysis resources; recent (2019) acquisitions are a fully automated, label-free high content screening platform, the Phasefocus Livecyte 2, allowing live cell imaging and automatic tracking (University funded), and a high-speed super-resolution confocal laser scanning microscope (Zeiss LSM 980 Airyscan2 (£283k BBSRC; **Higgins**). Outputs include: **Shackleton**, *PLoS Genet* 2014; **Wallis**, *Cell Rep* 2018; Fry *Sci Signaling* 2019.

• The **Electron Microscopy** facility, supported by a full-time manager (Natalie Allcock) offers scanning (Hitachi S3000H) and transmission (JEOL1400) EM, plus elemental analysis (EDX), Correlative Light and EM (CLEM), tomography and 3D EM. Outputs include: **Twell**, *Plant Cell* 2014; **Morrissey**, *Env Microbiol* 2017.

• The **Histology Facility** provides a comprehensive range of histological techniques and gained 4th place out of 300 participating pathology labs in the recent UK external quality assessment review. Supported outputs include **Oggioni**, *Nature Microbiol* 2018.

• The **FACS facility** (2017) was supported by the Wellcome Trust and a philanthropic donation and delivers a state-of-the-art flow cytometry service. It houses a BD FACSAria Fusion cell sorter and three analysers—a BD FACSCanto II, a Beckman Coulter Cytoflex and a BD Accuri C6 Plus.

• LeMID is supported by a **Containment Level 3 Facility** and the **Wolfson Category 2 Infectious Diseases Laboratory**, established in 2017 with matched University funding.

• The **Pre-clinical Research facility** provides access to animal models including mice, rats, rabbits, *Xenopus* and zebrafish, and is staffed by a team offering surgical services, training, and rodent breeding, and production of new gene-edited rodent models. Imaging equipment includes 9.4T high-field MRI, Quantum-FX X-Ray micro-CT, Vevo 2100 high-frequency ultrasound, and IVIS Spectrum bioluminescence/fluorescence scanners. These are used to study disease models such as ischaemic stroke, myocardial infarction, atherosclerosis, T-cell lymphoma, and streptococcal pneumonia. Outputs include: **Dubrova**, *Nature Commun* 2015; **Macip**, *Aging Cell* 2020.

• The PROTEX **Protein Expression Laboratory** provides a high-throughput service for cloning vectors for protein expression in *E. coli*, mammalian cells, baculovirus, yeast, *Drosophila*, *Xenopus* and cell-free systems, and CRISPR-Cas9 genome editing. Outputs include: **Millard**, *eLife* 2016; **Dalgleish**, *Nature Commun* 2016.

• NUCLEUS **Genomics Facility**, under a full-time manager (Nic Sylvius), includes Illumina MiSeq and IonTorrent PGM sequencing; ABI3500xl capillary electrophoresis; 10X Genomics Chromium Controller; microarray scanners; and quantitative PCR platforms. Outputs include: **Cowley**, **Schwabe**, *PNAS* 2014; **Jobling**, *Genome Res* 2016.

• All our PIs, ECRs and PGR students have free access to the University's ALICE2 and SPECTRE **High Performance Computing Facilities**.

• The Unit hosts the **Leicester Herbarium**, one of 20 major UK herbaria, founded in 1945, and incorporating collections dating back to the 18th century. It houses ~140,000 specimens, including reference specimens for a high proportion of the British Flora. Additional support for research and outreach in plant sciences comes from the 16-acre **Botanic Garden**, founded in 1921.

All these facilities are supported through central budget and staffed with expert EOs and technicians.

Cross-HEI collaborative use of research infrastructure

We collaborate closely with local Midlands universities as exemplified by our DTPs—our BBSRC, MRC and NERC programmes together involve the Universities of Warwick, Birmingham and Nottingham. PGR students in these programmes spend time in other institutions and a cross-fertilisation of ideas occurs as a result.

UoL is engaged in the strategic partnership **Midlands Innovation** (MI), evolving from the M5 consortium in 2016, and including Birmingham, Leicester, Loughborough, Nottingham, Warwick, Keele, Cranfield and Aston. MI promotes sharing of research infrastructure and equipment, its committee (UoL's academic member **Jones**) meeting bi-monthly. This is facilitated by an online database including >1000 shareable items from all institutions, from electron microscopes to MRI machines to 3D printers.

The Midlands Mass Spectrometry Group has built a regional community hosting seminars and sharing best practice to provide a platform for collaborative rather than competitive bids, strengthening funding applications. The Midlands Flow Cytometry Group fulfils a similar role for this research area, hosting the Annual Flow Cytometry Conference.

The Midlands Cryo-EM facility provides an excellent example of a successful collaboration within the MI group. The Leicester facility, in the Henry Wellcome Building, is supported by an ecosystem of feeder microscopes at Birmingham, Nottingham and Warwick. UoL co-led a successful EPSRC bid to establish a regional 1GHz biological NMR instrument (housed in Birmingham).

Our WTISSF includes an Institutional Partnerships scheme supporting bids from PIs or post-docs to link with another UK institution, e.g. to spend a research period there, learn a new method, or use specialised equipment. The Crick Institute is just over an hour away by train; so far the scheme has sponsored six Crick PIs to visit UoL to give seminars and discuss research collaborations and there have been six return visits to the Crick for training, seminar attendance and discussion of Public Engagement strategies.

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

Collaboration with and contribution to the research base

We are a highly collaborative Unit that contributes significantly to national and international research. Of the 1090 total outputs of the members of this UoA in the current REF period, 61% involved collaborations outside the UK, and a further 24% involved co-authors from other UK institutions (for our 152 submitted outputs, respective figures are 66% and 28%).

University funds to support collaborations are competitively available via the International Research Development Fund and our interdisciplinary institute LIAS, supporting Networks and 'Tiger Teams' (Section 1). Such groupings typically involve PIs across a wide range of subject areas plus external partners from the UK or overseas.

Strong international partnerships are reflected in our involvement in five EU-funded ITNs (see Section 2), and we are involved in major international research projects:

Talbot was Biomarker Lead in REQUITE, an EU-funded programme studying predictive models and biomarkers of radiotherapy toxicity to reduce side-effects and improve quality of life in cancer survivors.

Vuister leads the **Collaborative Computing Project for NMR** (CCPN), which links new and existing NMR software via a common data standard and provides a discussion forum within the community. CCPN began in 1999 in the UK and is now a network of 28 international partners. MRC support has been continuous since 2013, and comes from two MRC grants totalling £1.67M (**Vuister**, PI), recently supplemented by a new award of £1.6M.

Dominguez's collaboration with Frederic Allain (ETH Zurich; *Nucleic Acids Res* 2014) led to a BBSRC award (£399k to UoL). He partners with the European Lead Factory (ELF) to screen their compound library, bringing an in-kind contribution of £600k.

Schwabe is a co-investigator in a $6M Leducq international network, *Cellular and systemic cholesterol transport in physiology and disease,* linking UK, USA, Switzerland, Denmark, and Finland and bringing $731K to UoL.

Impact and engagement: collaboration and contribution beyond the academy
Our engagement and impact stretches from the local to the global. Within Leicester, **Fry**, through his WTISSF leadership, has promoted engagement with Leicester City Council, leading to projects on air quality and health, and mental wellbeing of people with multiple chronic conditions. Prof Ivan Browne, Leicester's Director of Public Health, is a member of our WTISSF Governance Board. TB researchers (**Amrani**, **Mukamolova**, **Oggioni**, **O'Hare**) run joint projects with the NHS and Public Health England in Leicester. **King**'s involvement with the ground-breaking Richard III identification project, documented in **ICS4**, contributed to huge local economic benefit, with a gross value estimated at £79M, including construction of the Richard III Visitor Centre, >200,000 annual heritage visits to the region, and >1000 new jobs.

At the global level, we have engaged fully with the changing agenda around international aid and the GCRF. The University is ranked 37th out of >500 institutions from 75 countries in the inaugural international THE University Impact Rankings, which assess universities against the UN Sustainable Development Goals, using indicators across research, outreach, and stewardship. We work with a wide range of industrial partners, and a total of £4.4M came into the Unit during the REF period from commercial sources, while 18 patents were filed by staff. The strength of the relationships is reflected in co-publications—8% of all outputs in the REF period include commercial collaborators as co-authors, and these have a mean FWCI of 3.06, cf 1.63 for other outputs, underlining the research value of these links.

We have a diverse portfolio of iCASE partners:

• Forensic research (**May**, **Jobling**, with senior post-doc Jon Wetton) has attracted five partners: **Key Forensic Services**, one of the UK's largest forensic service providers; **Verogen**, a company designing innovative MPS approaches for forensics; **DNA Worldwide**, a direct-to-consumer DNA testing company offering ancestry and family-searching products; **Oxford Nanopore Technologies**, inventors of 'third-generation' portable sequencing technologies, here being used to combat the illegal wildlife trade; **Twycross Zoo**, focused on research for rapid species identification to counter illegal wildlife exploitation. Wetton won a USAID Wildlife Crime Tech Challenge award in 2016 ($10K).

• Other iCASE relationships reflect **Oggioni's** expertise in bacterial genetics (**Christian Hansen** is a dairy industry company supporting a project on *Lactobacillus*, while **GlaxoSmithKline** supports work on pneumococcal niches within splenic macrophages); **KWS UK Ltd.** supports fundamental work on recombination in wheat, aiming to break up the long linkage groups that impair plant breeding (**Higgins**); brewing giant **SABMiller** supported **Louis'** project to develop better yeast strains for beer production, then partnered in a successful collaborative £1M BBSRC project (2014; Leicester, Nottingham, Manchester), bringing £400k to UoL; the **Defence Science and Technology Laboratory** supported two studentships studying *Burkholderia* (**Mukamolova**); **Jaguar Land Rover** sponsors **Morrissey's** EPSRC studentship on the effects of air pollution on bacteria; other partners are **Waters Ltd**. (**Jones**), **Isomerase Therapeutics** (**O'Hare**), **AstraZeneca**, **Boehringer** (**Amrani**), **AxialD3** (**Talbot**), **Cranswick** (**Clokie**).

Particular PIs have developed strong relationships with industrial partners that support their research activities:

• A spin-out company (**Haemostatix**) founded in 2013 (**Goodall**) was sold in 2016 to **Ergomed plc** following a successful phase 1 clinical trial of its lead product, a topical haemostat to prevent post-surgical bleeding. **Goodall** has also been PI/Co-I on projects funded by **Hoffmann-La Roche Ltd** and **Astra Zeneca** studying the mechanisms of actions of drugs in relation to cancer therapy.

• The leading direct-to-consumer genetic testing company **23andMe** supported **Beleza**'s work by funding whole-genome sequencing of her African human population samples (£198k), a collaboration reflected in a high-profile output (Micheletti, *AJHG* 2020).

• **Carr**'s long-standing research relationships with industrial partners (**ICS1**) led to a £1.35M award (2015) for the Antibody-Assisted Drug Discovery Consortium (**LifeArc**; **UCB Biopharma**) and a £1.74M CRUK Centres Network Accelerator Award (2016). The relationship has supported development of an anti-TNF-α antibody (Cimzia), an effective therapy for Crohn's Disease and other inflammatory conditions which has generated multi-billion euro total net sales to date, and the recently licensed anti-sclerostin antibody Evenity.

Public engagement

PE is key to our activities as a University and a Unit, and bolstered by the presence of **King**, Professor of PE; our College PE Manager, Marie Nugent, is working with the National Co-ordinating Centre for PE to develop an institution-wide **PE for Research** strategy, a milestone in facilitating culture change. We support and run outreach and PE events to showcase our research to various publics:

• **Dynamic DNA** is an annual genetics-themed STEM event, run since 2009. 600 key stage-3 students and their teachers attend, supported in exciting hands-on activities by academic staff and PGR students.

• **Brain Awareness Day** is an annual 1-day event, run since 2014 during National Brain Awareness Week, and hosts >200 key stage 4/5 students during the day, and 150 members of the public in the evening to learn about our neuroscience and behaviour research.

• Members of LISCB use VR headsets to demonstrate the wonders of structural biology to the public, including to schools at the **Big Bang Science Fair**.

• We participate in national events such as the **British Science Festival**; in 2019 the WTISSF-funded project *Hair Comes the Science Bit* involved a pop-up hair lab in a local hairdressing salon, revealing the fascinating science of hair to an audience not normally engaging in science events.

• Our **Botanic Garden** is the single biggest provider of outreach and PE in the University. It hosts >11,000 school, college and university students annually from across the city, county and further afield, plus >3000 adult students on taught programmes, and >40,000 diverse visitors from our local and wider communities.

• A new WTISSF scheme with the local Attenborough Arts Centre provides £5k awards to host a **Creative Fellow** to support innovative thinking and problem solving for research engagement and knowledge exchange.

Influence and esteem
The majority (94%) of our PIs hold external roles (many with multiple engagement) and/or have been recipients of prizes, awards or fellowships.

Prizes, Awards and Fellowships: 20 members of the UoA won a total of 30 accolades from learned societies (including Royal Society of Biology, British Pharmacological Society and International Society of Antimicrobial Chemotherapy), funders and other bodies over the REF period. Research fellowships included **Tufarelli** (WT Career Re-Entry Fellowship); **Cowley** (MRC Senior Research Fellowship); **Moody** (Royal Society Wolfson Fellowship; 2019); **Revyakin** (Leukemia & Lymphoma Special Fellowship). **King**'s work on the Richard III discovery led to the 2018 JBS Haldane Lecture of the Genetics Society and the British Council's Queen's Lecture in Berlin, 2016. She became a Fellow of the Society of Antiquaries of London, and Honorary Fellow of the British Science Association. **Panne** gave the 2014 Jean-François Lefèvre Memorial Lecture, Strasbourg, and **Clokie** gave the 2016 Otto Wolff Lecture at UCL Institute of Child Health. **Louis** and **Jobling** were awarded Honorary Professorships at Hubei University of Medicine (China), and **Vuister** at the University of Birmingham. **Schwabe** won a Royal Society Wolfson Research Merit Award and was elected member of Academia Europaea (2015). **Kyriacou** has been a Fellow of the Academy of Medical Sciences since election in 2000.

Roles in Learned Societies, Government Agencies, Advisory Boards: 25 UoA members (>40%) contributed to these activities, including roles in ten learned bodies ranging from the Genetics, Microbiology and Biochemical Societies to the Association for Radiation Research (**Talbot**, Secretary and Chair-Elect), Human Genome Variation Society (**Dalgleish**), European Society of Clinical Microbiology (**Oggioni**), International Association of Sexual Plant Reproduction Research (**Twell**, Vice-President), and the Galton Institute (**King**, President). Staff have been involved in government working groups (e.g. Home Office Biometrics and Forensics Ethics Group [**Jobling**]; European Food Safety Authority [**Louis**]; Food Standards Agency [**Clokie**]; Department of Health [**Dubrova**]), and in advisory boards (e.g. Earlham Institute; Warwick MRC DTP; BBSRC Bioscience for Sustainable Agriculture and Food Strategy Advisory Panel [**Ketley**]), thus helping shape both the national and international science landscapes. **Heslop-Harrison** has served on the UoA5 panel for both REF2014 and REF2021.
Conferences: During the REF period 30 international meetings were organised/co-organised by Unit members, including four EMBO and two Gordon Conferences. Members gave >290 invited or plenary conference presentations, plus a similar number of invited national and international seminars, equating to ~10 such talks/FTE over the REF period. This indicates both our

engagement in national and international science, and the high regard in which our researchers are held.

Grant review panels: 47% of staff contribute to funders as panel chairs or members**,** including 17 international bodies, e.g. Agence Nationale de la Recherche (**Dominguez**; **Oggioni**; **Louis**; **Amrani**), Institut Laue Langevin, Oak Ridge National Laboratory and NordForsk (**Moody**); Commonwealth Scholarship Commission (**Jobling**); Ehlers Danlos Society (**Dalgleish**). Staff sit on UKRI grant committees including BBSRC (7), MRC (2) and Future Leaders Fellowship panels (2). **Moody** chairs the Life Sciences Panel at Diamond Light Source, and **Schwabe** chairs Wellcome's Multi-user Equipment Committee. **Kyriacou** sits on Royal Society panels for Dorothy Hodgkin, Isaac Newton and RS Fellowships. Quinquennial review panel members include **Ketley** (BBSRC), **Goodall** (MRC), **Heslop-Harrison** (Czech Academy of Sciences; Hong Kong Baptist University) and **Louis** (Insitut Pasteur). Over 85% of staff have reviewed grant applications, underlining the esteem of members of the UoA and their contribution to UK and international science.

Contributions to journals, books and public understanding of science: 41% of UoA staff were editors or associate editors for 43 journals during the REF period. This includes editors-in-chief of *PHAGE* (**Clokie**) and *Annals of Botany* (**Heslop-Harrison**), plus: *Biotech Applied Biochem; Cell Tissue Eng* (**Brindle**); *Biochem Pharmacol; Brit J Pharmacol* (**Challiss**); *Sci Rep* (**Cowley**); *Hum Mutat* (**Dalgleish**); *BMC Biochem* (**Dominguez**); *Mutat Res; Radiation Biol;* (**Dubrova**); *PLoS One* (**Fry**); *Platelets* (**Goodall**); *Theor Appl Genet* (**Heslop-Harrison**); *Biol Meth Protocols; Front Genet* (**Hollox**); *Ann Hum Genet* (**Jobling**); *J Biol Rhythms; Behav Genet* (**Kyriacou**); *Yeast; PLoS One; Microb Cell; Sci Rep* (**Louis**); *Cell Death Disease; Sci Rep* (**Mahaut-Smith**); *FEMS Microbiol* (**Millard**); *Front Cell Infect Microbiol* (**Mukamolova**); *Infect Immun; Microb Cell* (**Oggioni**); *J Med Mycol* (**Pashley**); *Front Oncol* (**Rufini**); *Struct Biol* (**Schmid**); *Mol Cell Biol* (**Schwabe**); *Cancers* (**Talbot**); *Plant Reprod; BMC Plant Biol; Eur J Plant Sci Biotech; Int J Plant Devel Biol* (**Twell**); *J Biomol NMR* (**Vuister**); *Immunobiol* (**Wallis**); *Pharmacol Res Perspec* (**Willets**); *Sci Rep* (**Yesilkaya**). UoA staff contribute substantially to the peer review process, reviewing an average of 500 manuscripts/y over the REF period (>8 FTE/y). **Fry** and **Challiss** are Members of *Faculty of 1000.*

Contribution to PhD student and ECR training: 45% of UoA staff have acted as external examiner during the REF period for 79 PhD students in Europe, Asia, Africa, Australasia and the Americas, including institutions such as the Universities of Aarhus, Braga, Brno, Debrecen, Lausanne, Padova, Tartu, Umea, Vienna, and Wageningen; Karolinska Institute; ETH Zurich; EMBL Grenoble; Carnegie Mellon University; University of Los Andes; University of Peshawar. Within the UK, 73% of staff have acted as external examiner for >200 PhDs. The number and quality of our own students, and our role in examining students at national and international levels represent a significant contribution to the research base.

UoA5 Environment overview

Here we have described our vital and sustainable approach to Biological Sciences research at Leicester, and demonstrated our success in attracting research income, training the next generation of researchers, and producing high-quality outputs and impact. We are proud of the diversity of our city, and proud that our undergraduate student body and PGR students, as well as our vision for the future of our academic staff, reflect Leicester's rich diversity. Aided by strategic investment in research institutes and specific projects, our interlinked research groups support traditional areas of strength and will embrace new opportunities, through an ethos of collegiality, communication and collaboration and deep interdisciplinary relationships between

UoA5 and medicine, public health, chemistry and social sciences. We have recruited outstanding new people and nurtured our existing staff, and our future strategy ensures we will continue to do this. We have developed outstanding research infrastructure, supported by ambitious external bids, and linked with other institutions, and with industrial partners. Our members play central roles in Biological Sciences research in the UK and internationally, and the impact of their work, reflected in our case studies, brings benefits in health, wealth, wellbeing and culture to our region and globally. Their excellence is supported by the quality of their publications, and by the range and number of their contributions. These achievements are underpinned by the quality of the research environment that we have built at Leicester, enabling a resilient, diverse, sustainable, portfolio of support allowing us to maintain and grow a world-class research endeavour to address the most important and exciting biological challenges.