Institution: University of Bath

Unit of Assessment: UoA5 Biological Sciences

1. Unit context and structure, research and impact strategy

Unit context and structure

Research in the Biological Sciences (Biosciences) at Bath has grown since REF2014, undergoing transformative change and enhancing our excellent international reputation. Our 48 (46.2 FTE) academic staff conduct research across the full breadth of Biosciences. Housed within the Department of Biology & Biochemistry (B&B), our research is organised within four complementary themes: **Cell and Developmental Biology (CDB), Evolution and Biodiversity (E&B), Infection and Immunity (I&I),** and **Medical and Industrial Biotechnology (MIB)**. Individuals work across multiple themes, and typically belong to one or more networks or University research centres. Outstanding among these is the *Milner Centre for Evolution (MCE)*, the major (£8.3M) investment in the Unit within the REF period. The *MCE* integrates and enhances work from the **E&B** and **I&I** themes and also has strong interdisciplinary links. Another University centre (*Centre for Mathematical Biology)* and a University-wide research network (*Cancer Research @ Bath Network*) are led by Biosciences academics. Through implementation of our research strategy, in the REF period we have achieved:

- Grant capture (funds awarded) almost doubled from £16.2M (REF2014) to £30.9M
- Publications increased from 702 (REF2014) to 868; 18.8 publications/FTE; 545 with international co-authors (up from 414); 154 papers[1] published in *Nature* and *Cell* suite of journals, *Science* or *PNAS*
- Outputs with industrial partner increased from 38 (5.4%) to 51 (6%)
- 10% net growth of staff numbers: 21 new academics appointed (81% junior appointments, including 20% externally funded fellows); 15 staff promoted
- Gender balance improved, from 18% female (2014) to 33% (2020), and Athena Swan Silver Award achieved
- Number of PhDs awarded increased from 84 (REF2014) to 125 FTEs
- A prestigious European Research Council Advanced grant awarded
- Members of staff elected Fellow of the Royal Society, the Academy of Medical Sciences, the British Pharmacological Society, and the Hungarian Academy of Sciences

Research and Impact Strategy We aim for excellence, through collaborative approaches, promoting synergies between fundamental understanding of key biological principles and industrial and societal needs. Recognising the increasing importance of interdisciplinarity, our recruiting goal during this REF period was to appoint outstanding academics to consolidate and bridge existing research strengths. Our strategy to enhance our research quality, quantity and impact as set out in REF2014 comprised:

1) Providing the **support to excel** in individual excellence-led basic research, whilst encouraging **alignment and responsiveness to key problems** in the realms of Public Health, Climate Change and Food Security;
2) **Building collaboration and interdisciplinarity**, through research centres and links with external research partners in international centres of excellence;
3) **Balancing pure and applied research**, to enhance impact;
4) **Building on research strengths through recruitment** of internationally recognised researchers.

We have successfully implemented each component of this strategy within the four Research Themes (each of critical mass and boosted with new recruits) and used Centres and related groupings to promote interdisciplinary research, exceeding our REF2014 aims, as described in the following sections.

[1] 106 if exclude *Scientific Reports*

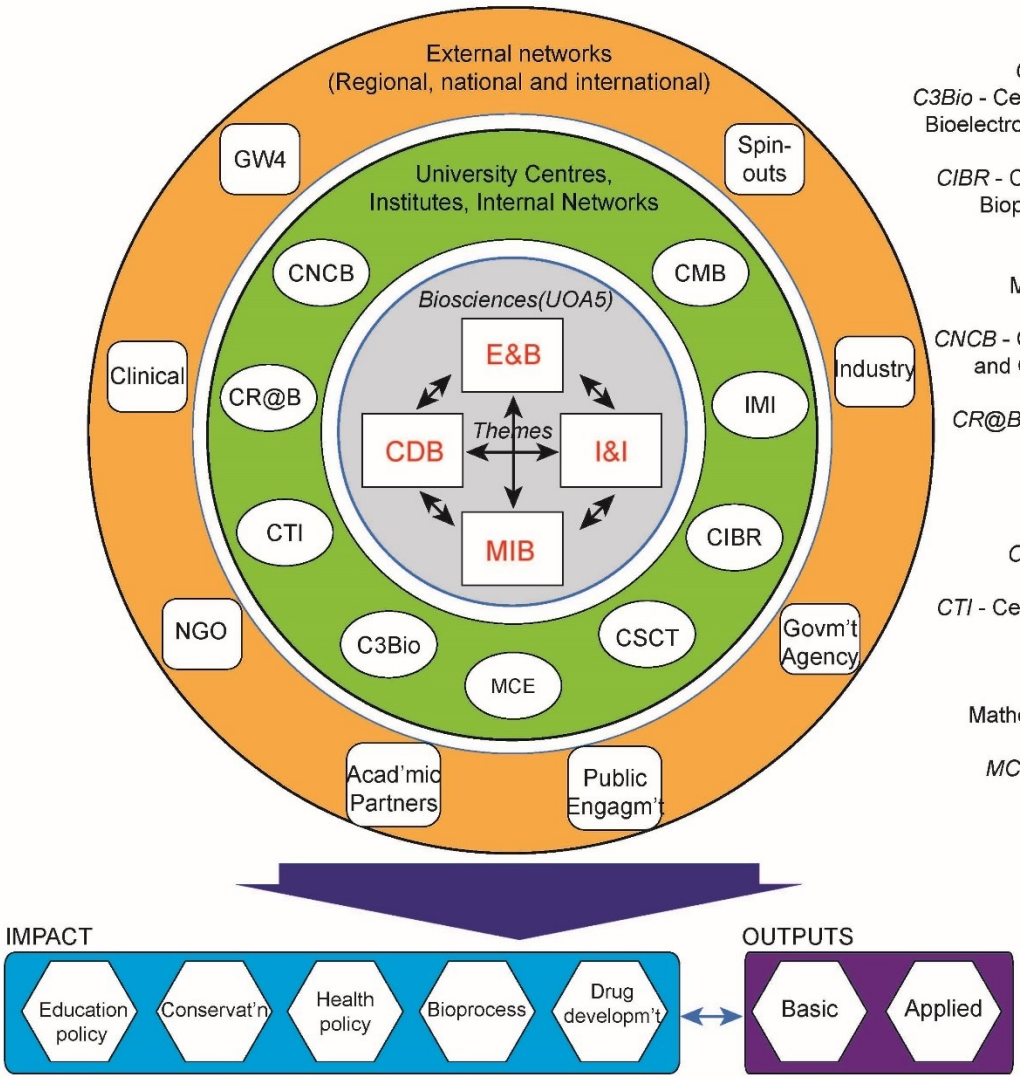

Figure 1 University of Bath Biosciences in its collaborative context

Research Themes: Selected highlights and future focus

Cell and Developmental Biology (CDB) (17 groups; total grants awarded £10.2M): addresses fundamental questions in cell biology and eukaryotic development. We have defined the role of imprinted genes in regulation of neural stem cell function and inter-generational effects on adult health (Ward: *PLoS Biology*, *Nature Comms.*), achieved the mechanistic dissection of long non-coding RNA and 5-formylcytosine and 5-hydroxymethylcytosine functions in cell cycle progression and cancer (Murrell: *Nature Comms., Nature Chemistry, Nature Chemical Biology, Genome Biology*), and shown that hypomethylation of pollen circumvents the interploidy hybridisation barrier, opening new routes for improvements in plant breeding (Scott: *Plant Cell*). *CiteAb* is now the go-to resource for antibody reagents (Chalmers, *Impact Case*). We have also identified the crucial role for YAP signalling in maintenance of body shape (Bagby, Furutani-Seiki: *Nature*) and, through pioneering use of injected nanodevices, we are revolutionising understanding of intracellular forces during the earliest stages of development (Perry: *Nature Materials*). Our research questions are relevant to human health and ageing (especially neurodegeneration, cancer and diabetes), developmental biology, stem cells and regenerative medicine, and Food Security. We see ongoing opportunities for fundamental contributions to Biomedicine, especially through the genetic and epigenetic basis for stem and cancer cell regulation, cell signalling and the biophysical study of development.

Evolution and Biodiversity (E&B) (13 groups; total grants awarded £6.2M): addresses evolution at all organisational levels from genes to populations, and over all timescales from the evolution of microbes over a few days to the history of Life. We have shown that strategic investment and a

polychromatic 'greenbeard' locus explains patterns of cooperation and cheating in Dictyostelium (Wolf: *PNAS, Nature Communications*), and that primate-specific endogenous retrovirus-driven transcription defines naive-like stem cells (Hurst: *Nature*). Key contributions to understanding the impacts of Climate Change and Food Security include defining the phenological and fitness changes in plants responding to simulated climate warming, and changed demographics and predation in wild bird populations (Kover: *Global Change Biology*; Szekely: *Science, Nature Climate Change;* Younger: *PNAS*), elucidating mechanisms driving variation in adult sex ratio, and its consequences for parental cooperation, mating system and population growth (Székely: *Nature, Nature Communications, PNASx2*), and how a specialized metabolic network selectively modulates Arabidopsis root microbiota (Nützmann: *Science*). A distinctive educational contribution identifies how best to improve the understanding of evolution (Hurst, *PLoS Biology, Nature Ecol. Evol, NPJ Science of Learning*). Major future opportunities concern understanding how new species evolve and adapt, impacts of environmental change (natural and anthropogenic) on species range and extinction, and how evolutionary principles can improve human wellbeing.

Infection and Immunity (I&I) (11 groups; total grants awarded £7.2M): aims to understand how pathogenic microbes interact with their human, plant or animal hosts. Numerous studies inform our understanding of the genomic traits determining virulence and disease outcome in bacterial and parasitic infections (Laabei, Sheppard, Feil, Massey, Hunt, Priest, Preston, Cowley, Bagby: *Nature Microbiol., Nature Ecol. Evolution, Nature Comms.x2, PLoS Biology, PNAS, Genome Biol., BMC Biology, J. Infectious Diseases, PLoS Computational Biol., J. Anim. Ecol., Sci. Reportsx3, Microb. Genomics*), and the spread and evolution of bacterial diseases, including the development of antibiotic resistance in real time as crucial leverage in preventing resistance development (Feil, Sheppard: *Environmental Microbiol., Microbial Genomics*). Key translational outcomes include novel approaches to vaccine development by exploiting immunomodulatory proteins as vaccine adjuvants or capitalising on immune responses to asymptomatic carriage (Preston, van den Elsen: *Clinical Infectious Diseases, Frontiers Immunol.*), and development of new technologies for real-time sensing of bacterial infections and for high-throughput screening of new therapeutic interventions (Jones: *Biosensors and Bioelectronics, Frontiers Cell. Infect. Microbiol.*). With research so directly relevant to Public Health and Food Security, and in close alignment to the University's strategic priorities in antimicrobial resistance (AMR) and Climate Change, we see numerous opportunities for future work on, for example, mechanisms and spread of virulence/antibiotic resistance, molecular epidemiology (e.g. **Feil** awarded EPSRC funds for COVID monitoring in waste water (08/2020)), host-microbe interactions, and biotechnological applications of microbes and their products.

Medical and Industrial Biotechnology (MIB) (7 groups; total grants awarded £7.2M): studies fundamentals of protein structure, function, dynamics, engineering and biological interactions at a molecular level with a focus on exploiting this knowledge to deliver advances in medical and industrial biotechnology. We have characterised the mechanistic underpinning of rare, but fatal, kidney disease (Acharya: *Human Molecular Genetics, Scientific Rep.)* and described the engineering of a thermophilic host for production of terpenes from waste materials (Leak: *Metab. Eng.*). Our novel technologies, including patented discoveries, have led to successful development of peptide-based therapeutics for inflammation (van den Elsen: *PloS Biology*), high mortality cancers (Mason: *ACS Chem. Biol.x3; Impact Case*)), detection of novel psychoactive substances using fluorescence spectral fingerprinting (Pudney: *Biochem. J., ACS Anal. Chem.*), and a novel method for microbial monoterpene ester production (Leak: *Mol. Cell Fact.*). The ongoing focus will be on developing new technologies addressing societal industrial and biomedical needs.

Strategy to promote collaboration and interdisciplinarity

Collaboration and interdisciplinarity are embedded in our research culture and facilitated by our research structures: *Research Themes* provide the organisational unit for research within the UoA, and interface with *Centres and Institutes* at Faculty or University-wide level (Fig. 1). Cross-department interdisciplinary collaboration is promoted through formal (e.g. dedicated seminar series) and informal interactions, facilitated by our compact campus.

Recognising the outstanding strength of our evolutionary biologists, a key strategic investment was in the *Milner Centre for Evolution (MCE*; 2018; Directors, Hurst, Wills). The *MCE* is housed in a new £8.3M building and has a tripartite mission for blue skies and applied research and education/outreach. The Centre resulted from the University's largest single donation to date (£5.6M) from Jonathan Milner (alumnus and co-founder of Abcam), plus contributions from Wolfson Foundation and Garfield Weston, and studentships through the Evolution Education Trust. Bringing together our evolutionary biologists (**E&B**) and microbiologists studying evolution of pathogens during disease outbreaks and antibiotic resistance (**I&I**), the *MCE* is a flagship Centre within the University.

Within the REF period, a further three new centres with significant involvement of Biosciences have been founded, reflecting the integration of our research with the broader expertise in Bath and both national and international priorities:

- *Centre for Integrated Bioprocessing Research* (founded 2019, incorporating the former *Centre for Extremophile Research (*Director Danson). Bioscientists (from **CDB, MIB** themes) work with academics from Engineering Departments and industrial partners to de-risk the development of novel bioproducts. E.g. contributions in metabolic modelling and synthetic biology, engineering microbes to produce bulk chemicals from renewable feedstocks (Leak; *Metab. Eng.*).
- *C3Bio* is an interdisciplinary Centre embracing Engineering, Science and the Social Sciences, with a mission to use sensor technologies to address real world problems. Pudney's involvement in a cross-Faculty team (with Pharmacy and Pharmacology (P&P), Chemistry and Psychology) led to the first point-of-care drug detection system for synthetic cannabinoid receptor agonists (Spice; Pudney, *Anal. Chem.*).
- *Centre for Therapeutic Innovation* (founded 2017) incorporates the former *Centre for Regenerative Medicine (*Director, Tosh). *Centre for Therapeutic Innovations* takes fundamental biological research, notably membrane biophysics and signalling, through to drug discovery, development and commercial enterprise pipeline. Key involvement from Biosciences includes van den Elsen (co-lead of Mechanisms of Disease and Regeneration research stream), and academics with a drug development or detection focus (Mason, Pudney). Funding success includes joint bid for Light Sheet Microscope (BBSRC, Kelsh lead).

The *Cancer Research @ Bath Network (*Director, Murrell) links our cancer researchers with those in P&P, Chemistry and the Royal United Hospital (Bath), and facilitates collaborations within the regional GW4 Cancer network. The *Centre for Mathematical Biology* and the *Centre for Networks and Collective Behaviour*, together with the more industry-facing *Institute of Mathematical Innovation*, link researchers from **CDB, E&B** and **I&I** with those from the Departments of Mathematical Sciences, Computer Sciences and Physics; successes include major BBSRC grant (Kelsh, £1M). The *Centre for Sustainable and Circular Technologies* links Biosciences with Chemical Engineering, Chemistry and Mechanical Engineering, as well as stakeholders and industrial partners, and has a strong focus on bio-based resources and production.

Further opportunities come regionally from our GW4 partnership, which has resulted in numerous regional research groupings, including GW4 Cancer, GW4 Epigenetics, GW4 Climate Alliance, and GW4 Antimicrobial Resistance Alliance. Significantly, the UoA benefits from the drive of the GW4 partnership towards innovative PhD training, promoting joint PhD studentships, and first-class skills training. The GW4 partnerships also facilitate research applications, including multi-user large bids (e.g. MRC AMR in Thailand (£3M); Feil, £744K), and shared outputs (e.g. Feil: *Microb. Genom.*).

Our research strength has been further enhanced by international research partnerships. University-funded David Parkin Visiting Professorships have funded four overseas academics' visits to the Department. International (e.g. Newton Advance grants (3)) and local (e.g. Bath International Research Partnership Scheme) funding schemes have promoted collaborations with world class researchers at overseas institutions (e.g. Kyoto, Sao Paulo, Beijing University of Chemical Technology). The MRC CLIMB project (Sheppard) has attracted many visitors, including

from China, Thailand and Spain. Hunt is Co-I on a Japanese Science and Technology Agency CREST (270M Yen awarded), funding collaborative research in Japan, enabling her to maintain research activity in collaborators' labs, promoting interdisciplinarity and productivity. Mason partners with University of Queensland (MRC (£780K), plus BBSRC Partnering Award). The University has recently signed accords with seven partner universities on four continents, and the International Strategic Fund provides support for academics to initiate international collaborations with these institutions: e.g. six collaborative projects with institutions in Brazil and Uruguay, including funding from FAPESP-SPRINT, BBSRC-FAPESP, and the Bath International Relations Office.

Balancing pure and applied research

A key strength in Biosciences is translation of fundamental research into clinical, environmental, industrial and policy applications. This is achieved by encouraging all our academics to explore at an early stage potential application of fundamental research outcomes. UoA Impact Directors (Chalmers, Pudney) and other experienced academics (e.g. Danson, Leak) provide mentoring in this area. This is enhanced through **MIB** having a direct focus on industry-facing research and its commercialisation, and all our themes interface with multidisciplinary Centres that engage external partners, creating a pipeline to exploitation of research (Fig. 1). Sustained industrial collaborations are promoted through UKRI initiatives (e.g. Networks in Industrial Biotechnology and Bioenergy (NIBB: Leak, Henk); Integrated Biorefining Research and Technology Club (IBTI: Leak); MRC Developmental Pathway Funding Scheme (Jones); Innovate UK (Jones, Leak), EPSRC Impact Acceleration Accounts (IAA: Leak, Gebhard, van den Elsen, Pudney)), PhD studentships (e.g. iCASE and BBSRC Case: Preston, Mason, Acharya, van den Elsen, Scott, Feil, Jones, Pudney), scientific research agreements, consultancy and research grants. New industrial collaborations, developed through personal contacts or mediated via the University's Research and Innovation Services (RIS), are often supported directly or through entrepreneurial grants (e.g. Mason, CRUK Pioneer Award). These include Leak (Corbion, Croda, Fiberight, ABsugar, Molson Coors), Mason (Sapience Therapeutics), van den Elsen (UCB-Celltech, Porton Biopharma Ltd), Sheppard (Aviagen, Banham Poultry), Pudney (Qualasept, UCB-Celltech), Williams (Mars Edge). In other cases, direct translation of research was supported by RIS, alongside academic sabbaticals (e.g. Chalmers, CiteAb*;* Preston, GSK Biologicals, GSK Vaccines, PHE and Birmex). Two of these examples contribute to our *Impact Case Studies* (CiteAb (Chalmers); Sapience (Mason)). Other opportunities for impact arising from pure research are diverse, with our *other Impact Cases* resulting from opportunities presented due to our academics' 1) acknowledged specialist expertise resulting in playing a key role in developing science-related policy (Perry), and 2) recognising that key study populations would require protection, and founding an NGO to do this (Szekely).

Building on research strengths through recruitment of academics

Our recruitment in the REF period reflects and supports the UoA's research strategy. Strategic use of recruitments has boosted each Theme by complementing existing strengths, building critical mass, and developing new strategic elements. Themes identified priority areas for each recruitment round, looking to enhance strengths and bridge between themes wherever possible, realised by appointing established leading experts and up-and-coming early career academics, all with international recognition appropriate to their experience, and independent of background or protected characteristics.

These recruitments have been particularly effective in driving expansion within the **E&B** and **I&I** themes, fitting with the University and/or national research priorities of Food Security, Climate Change and AMR. Thus, within *Food Security* we have deepened our expertise in genomics by incorporating plant genomics (Nützmann (Royal Society URF)); established a prokaryotic genome sequencing facility, through recruiting a further microbiologist using genomics to address complex questions in the ecology, epidemiology and evolution (Sheppard (Director of Bioinformatics)); expanded and strengthened our research in plant-microbe interactions (Cevik, N.Brown (BBSRC Future Leader Fellow)). Within *Antimicrobial Resistance*: expanded and strengthened our research in host-microbe interactions (Gebhard, Laabei, Hunt (Sir Henry Dale Fellow)); strengthened the interface between microbiology and healthcare-associated applications (Jones, Cowley (Prize Fellow), Martinez-Urtaza (since recruited to CEFAS)); added (microbial)

experimental evolution to our core expertise (Taylor**,** Royal Society Dorothy Hodgkin Fellow). Within *Climate Change*: enhanced expertise in ornithological evolutionary and behavioural biology (Field, Prize Fellow (now Lecturer at University of Cambridge), Younger (Prize Fellow)). Recruitments in CDB, often bridging with the **E&B** and **I&I** themes, have targeted: enhancing our profile in RNA biology across disciplines (Denham, Vance, Hussain); extending cell biology and stem cell research, and enhancing cross-disciplinary cancer research (Walko, Sero); consolidating and expanding developmental neuroscience and zebrafish research (Nikoloau); expanding and diversifying capacity for working with large data sets, from bioinformatics to high content microscopy (Turner, Sero). Finally, a senior recruit bridges the **MIB** and **CDB** themes, reinforcing our strengths in developing new therapeutic technologies, notably for cancer and neurodegenerative diseases, and forging new industrial links (Mason).

Future strategic aims and goals

Our plans for future growth reflect a strong commitment from the University to support and nurture cutting-edge and interdisciplinary research, especially in the priority areas of Sustainability and Health and Wellbeing (*REF 5a, Section 1.5*), underpinned by investment addressing the most timely research questions and strengthening the collaborative networks internal and external to the UoA. Our strategy will build upon the key pillars established during this REF period: 1) **excellence-led research**, **aligned to real-world global challenges** in Public Health, Climate Change and Food Security; 2) **building collaboration and interdisciplinarity**; 3) **balancing pure and applied research** to enhance impact; 4) **building on research strengths through recruitment**, with a focus on fulfilling our EDI aims as set out in our Athena Swan Action Plan. The 21 newly appointed staff are now firmly embedded within the Department, with growing productivity in publications, grant success and internal and external collaborations. With many recruited in the last two years, further growth in their grant success and outputs will be enabled by the support mechanisms outlined below. AMR and Climate Change are particularly ripe for expanded activity here, being increasingly recognised as urgent challenges. Feil and Gebhard represent our cluster of eight academics and others on the cross-university Steering Group, within the new GW4 Strategic Alliance on AMR. Our cutting-edge research into bio-based renewable resources (Leak, Henk), food security (N.Brown, Cevik) and conservation of biodiversity (Younger, Szekely) is contributing to tackling the climate emergency and mitigating its global effects. With increased targeting of these areas by funding agencies, we are strategically poised to expand and diversify our local, regional and international collaborative networks. We will continue to explore appointments exploiting interdisciplinary opportunities at Theme interfaces, for example, between **E&B** and other themes.

Our significant focus on impact will be further enhanced, especially through Knowledge Exchange and Innovation. This is an area of strength for the **MIB** theme and, due to recent staff changes, is the current priority for targeted recruitments. Recent investment in our Zebrafish facility enables expansion of the use of this cost-effective model for biomedical and fundamental biosciences, including *in vivo* stem cell biology. The impact-focus of such appointments would enhance Biosciences involvement in *Centre for Therapeutic Innovations.* Faculty initiatives to support early development of potential commercial ideas and investment in activities of those centres with an explicit commercial ambition (e.g. *Centre for Therapeutic Innovations* and *Centre for Sustainable and Circular Technologies*), will be exploited alongside national programmes to enable both established and early career academics and our early career researchers (ECRs, here used for PhD students and PDRAs) to identify and seize opportunities for commercial exploration of research ideas. This will be enhanced by GW4-wide initiatives; for example, the current BBSRC SWBio DTP incorporates UCB, Rothamsted Research and SETSquared as partners. Biosciences academics regularly secure CASE (7 during REF period) and other studentships with industrial funding (6 in period), testifying to our ability to liaise with external partners. Together with public outreach, including through the *MCE* programme, these will enhance the visibility and impact of our research and researchers through the coming REF period.

Strategy for an open research environment and a culture of research integrity Openness and research integrity are important to the UoA; we utilise the University's robust and transparent policies regarding research governance including infrastructure, data storage and management,

use of animals and human tissue in research, grant management and regulatory issues. Written policies (available online) are augmented by on-site training in research ethics. Ethical review is provided by, for example, the Animal Welfare and Ethical Review Board, under the oversight of the University Ethics Committee. Library Services oversee utilisation of Open Access Funds, RIS offer support for compliance activities, and the Unit benefits from the GW4 NC3Rs regional programme manager, who works with academics and researchers to help sustain and grow research activity while ensuring best practice in governance. Subramanian gave the NC3Rs lecture at a GW4 showcase (2020). All Biosciences staff undergo online training, with annual refresher courses, e.g. on Recruitment and Selection processes, diversity, unconscious bias, academic integrity and Data Security. Our open research policies have resulted in 83% of outputs since Apr/2016 being green or gold open access.

2. People

Staffing strategy

Our focus is on recruiting and nurturing first class researchers of all levels, independent of background or protected characteristics, striving to maintain a supportive research environment within which all can excel. As academic research staff teach, our staffing strategy considers both research and teaching needs. Research Theme Leads/Deputies identify research strengths to be highlighted to the Department Research Committee for strategic planning of research priorities and recruitment, before discussion at Department Executive. The primary emphasis at shortlisting and selection is on research quality of the applicant and fit with the UoA's research interests and vision, with a clear focus on EDI (see below). All new appointees receive a start-up package suited to their discipline and position, with a primary aim to ensure they achieve independent research productivity as soon as possible.

We appointed 21 new academics during the REF period. These recruitment opportunities resulted from retirements, expansion around PGT portfolio, University Prize Fellowships (Cowley, Younger; also Diezmann, Field, and Munoz-Descalzo) and direct investment in the *MCE* (Nützmann, Sheppard, Taylor). One recruitment priority was to strengthen and consolidate existing research excellence in molecular microbiology, genomic evolution, plant sciences, developmental biology and therapeutic technology development, as detailed in *Building on research strengths* (p. 5).

University commitment to the establishment of the flagship *MCE* recognised our international excellence in evolution research and teaching and included the provision of three University Prize Fellowships for evolution research (Cowley, Younger and Field). In addition, the MCE attracted two further appointees as University Research Fellows (Nützmann, Royal Society URF, £475K; Taylor, Royal Society Dorothy Hodgkin Fellowship, £480K). Together with new appointments in the MCE-facing **I&I** Theme (N.Brown (BBSRC Fellowship, £157K), Cevik, Denham, Gebhard, Hunt (Wellcome Trust Henry Dale Fellowship, £875K), Jones, Laabei, Shepherd), this provided critical mass and cemented the MCE as a world-class centre in evolutionary biology.

We also strengthened links across Departments and Centres, with all new appointments rapidly becoming well-integrated. For example: Gebhard's applied and interdisciplinary work involves cross-departmental relationships with Mathematical Sciences and Civil Engineering, and interfacing with *Institute of Mathematical Innovation* and *Centre for Sustainable and Circular Technologies* (EPSRC, £836K); Jones interacts closely with Chemistry, Chemical Engineering and Electrical and Electronic Engineering and with healthcare providers; Walko and Sero have already developed strong collaborative links to P&P and *Centre for Therapeutic Innovations.* Interaction with this Centre has been further enhanced by recruitment of Mason. Development of links to *Institute of Mathematical Innovation* has been achieved through a formal six-month secondment scheme; three UoA members have already participated.

We also further strengthened our international profile; all new recruits bring established international partnerships. For example, N.Brown has long-standing collaborations with partners in Europe and South America (13 publications, including *Nature Microbiology* and *mBio*); Cowley with partners in North America, Europe and Asia (19 publications including *Nature, Plos Genetics*

and *mBio*); Younger with partners in Australasia, North and South America, Europe and Africa (11 publications, including *PNAS* and *Global Change Biology*).

A key recruitment aim was to provide more female role models and address the gender imbalance. Having obtained a Bronze Athena SWAN award in 2015 we secured our Silver award in 2020. This went hand-in-hand with improving our recruitment practice (see Equality and Diversity below) leading to all advertised academic posts attracting outstanding female applicants and the gender balance improving from 18% female in 2014 to 33% in 2020. Three women attended the HE Aurora course (Crennell, Murrell, Urrutia), with two senior academics acting as role models (Murrell, Wonnacott).

All appointees start on, or are expected to transition to, an open-ended contract. We have invested in recruiting talented young academics through research fellowships. N.Brown has already progressed to an open-ended position; the others are on track to do so.

Succession planning is critical to maintaining research activity; changes in retirement age and employment law, deaths and chronic illness, and staff accepting positions elsewhere have all impacted us in this REF period. Our Theme-based organisation, co-teaching policy, shared lab space, PhD supervision and other measures have proven to be robust against major negative impacts, especially on shared responsibilities such as teaching. In terms of Biosciences leadership, key posts have fixed terms to facilitate succession planning (with open calls within the department for any vacancies) and nominated deputies mitigate against unforeseen changes.

Staff Development

The UoA has developed initiatives specifically tailored to support staff in the Biosciences at all career stages. These build on diverse Staff Development opportunities, targeted at enabling staff to excel in all aspects of their work whilst maintaining an appropriate work-life balance. These include the *Bath Course* which provides stage-appropriate training on teaching and research management, leading to Fellowship of the HEA upon completion. Initiatives for academics within the UoA include:

- *Training and Mentoring Schemes*: The University offers numerous training courses for new recruits, covering all aspects of academic responsibility. Academics are encouraged to choose one or more academic mentors in house and/or external to the University. Emeritus Professors and other senior academics in the Department provide informal advice to senior and less senior academics alike. Our mentoring of early career academics includes grant writing support, contributing to major grant successes (e.g. Gebhard: BBSRC and EPSRC, total £1.25M; Walko: BBSRC New Investigator, £536K; Vance: BBSRC New Investigator, £514K; Hussain: BBSRC £458K), and resulting academic promotion to Senior Lecturer (Gebhard, Hussain, Vance). University Research Fellows receive commitments to open-ended contracts.

- *Support for achieving Impact*: Achievement of impact is a major priority within the UoA, with opportunities for individuals to shift focus from basic to applied research where valuable, and extensive central support provided by RIS (e.g. via IAA funding). Chalmers' impact case was directly supported in this way, enabling him to focus on development of CiteAb at a crucial stage. Flexibility of academic staff time also plays a major role in achieving impact, with Perry's impact case dependent upon his commitments allowing sufficient time for his contribution to national policy development. More generally, and especially at the early stages of exploration of impact opportunities within an individual's research programme, support from RIS on IP protection and integration with the resources of the SETSquared partnership; peer mentoring from experienced colleagues, both within the Department (e.g. Leak) and elsewhere (e.g. numerous colleagues in P&P); introduction to potential industrial or other collaborating or exchange organisations; and impact generation events such as workshops and Centre meetings, all provide effective opportunities to build impact.

- *Sabbatical leave:* The University operates a formal programme of sabbatical leave entitlement, managed by the PVC (Research). Successive Heads of Department have encouraged the uptake of this opportunity, recognising the positive impact it can have on research progress,

e.g. both Szekely and Wolf used sabbatical leave to work at the Berlin Institute for Advanced Study, enabling the UoA to strengthen its links with that institute.

- *Promotion planning*: We have an annual staff development and performance review in which staff discuss their career development and assess their readiness for promotion. Improved communication of promotion criteria, now including outreach and teaching excellence, has led to greater transparency and 80% success rate for applications; 33% of UoA staff were promoted during the REF period. Staff considering application for promotion are assisted by a Departmental Promotions Committee that formally considers applications and provides advice to the applicant in time for changes to be implemented before submission to the appropriate University committees. Within this process development needs are highlighted, and the Department can provide support for attending specialist and leadership training.

- *Workshops and training events*: Within Biosciences, local, highly effective innovations have included both user-groups and regular workshops around research interests. These include Bambu (coding workshop for bioinformatics) and *C3Bio* (workshops on nanobiology).

- *Maternity/Paternity/Parental leave support*: During this period two academics have taken maternity leave and four paternity leave. Several staff use University childcare facilities. During this period, promotions and transitions to open-ended appointments included those with caring duties, and illness/disability. Feedback from staff who have taken leave has been positive and we have appointed a Research Parental Leave Officer (Taylor) to offer further advice and support for maternity/paternity/parental adoption leave.

- *Pump prime funding* The UoA has allocated funds for pump prime funding and equipment through an open call for competitive applications organized by the Research Committee. Staff can use these funds, for example, to address reviewers' comments to complete research papers, or to get preliminary data for invited grant applications.

- *Recognition and reward of staff for research and impact* The University recognizes outstanding contributions to research and impact through prizes and annual contribution pay awards scheme. During the REF period, UoA staff have been recognized through Excellence in Doctoral Supervision (van den Elsen, Danson) and Doctoral Recognition Awards (Wills), and eight academics and PDRAs benefitted under the pay award scheme.

- *Support for staff during COVID crisis* The UoA (and University) took a flexible approach to the COVID crisis, supporting staff and graduate students through 1-2-1s and virtual social events (mainly via the Theme structure), and operating a transparent system for a phased safe return to research activities, with technical staff providing invaluable assistance in identifying safe operational procedures. This was complemented at a University level by implementation of adapted policy and procedures to enable the return to research activities.

PDRAs are supported by our implementation of the Concordat to Support the Career Development of Researchers, delivered institutionally through the Research Staff Working Group. Within the UoA, we empower and support PDRAs through formal annual career review conversations. PDRAs are assisted in finding mentors external to their supervisory team and encouraged to participate in bespoke in-house programmes (Academic Career Academy Programme, science writing workshops; attended by 70% of PDRAs). These have prepared them for pitching research ideas (e.g. at GW4 Crucibles) and successfully applying for independent research careers. PDRAs are eligible for pump priming opportunities, e.g. Reeksting was given PhD-supervisory responsibility to develop independent research. PDRAs are now also encouraged to be co-applicants on grants where possible. PDRAs are represented on most of our Departmental committees and have important, informal roles during academic staff recruitment processes. They have their own in-house Society, PostdocBio, enthusiastically developed and run by themselves, to encourage networking opportunities. The Chairs of PostdocBio and PGBio (see below) meet monthly with the HoD and the Department makes a financial contribution towards

their social events. We encourage PDRAs to select mentors outside of their research supervisors and have mentoring coordinators who assist them in finding suitable mentors.

Research Students are a key component of our research strategy, which has resulted in an increase from 84 to 125 PhDs awarded in the REF period. Close connections within the GW4 network with Bristol, Cardiff and Exeter Universities broadens the regional research network, enabling sharing of excellent research infrastructure, delivery of outstanding doctoral training, staff development and collaborative research, enhanced through joint doctoral training programmes, ensuring consistently high standard of recruits. Awards for the various GW4-focused Bioscience networks (BBSRC SWBio, renewed in 2020 (Kelsh, Bath lead); MRC Biomed DTP; NERC GW4+ DTP (Wonnacott, Bath lead)) total more than £50M and play a vital role in our current and ongoing PhD student recruitment success. The Evolution Education Trust investment (£218K) in the *MCE* research programme, matched by University studentships (£350K), has funded seven students to date in the fields of evolution and evolution teaching. An international PhD programme with Monash University has begun and will continue to further enrich our graduate environment. A mixture of other sources funds other studentships, from alumni to international PhD programmes, adding further diversity to our cohorts. Stringent competition across schemes ensures that we recruit the highest calibre students from the UK and EU (internationally for the Evolution Education Trust); the University has recently committed to supporting international awardees for up to 30% of our UKRI studentship intake. Additionally, several excellent international students come to us through competitive government scholarships, often through our integrated MRes/PhD programmes. These include links with government studentship programmes in Mexico, Brazil and Paraguay (CONACYT), Taiwan, and China Scholarship Council, as well as formal MoUs with other institutions (e.g. University of Oslo, Monash University, UNAM, University de Sao Paulo, Nanjing University). Studentships are awarded independent of background or protected characteristics, based on academic achievement and self-motivation; progress is monitored though formalized procedures with monitoring at 6-month intervals by the Doctoral College. Those on formal DTP programmes receive an extensive bespoke training programme (with many aspects also promoted to other students). For example, the GW4 SWBio DTP has a strong emphasis on cohort building across the DTP, giving students numerous opportunities to make contacts in each of the partner universities and associated organisations, intensive generic skills-training sessions located at each of the partner institutions, annual symposia, and theme-based activities. An invaluable opportunity is provided by the Professional Internships for PhD Students scheme, during which students spend 3 months outside their research area, gaining novel experience and contacts in a career-relevant work-setting.

PhD students are represented on most of our Departmental committees and contribute, informally, to academic staff recruitment processes. Networking is promoted through an in-house society, PGBio. Membership of a suitable learned society is funded to enable engagement with their national research forum (e.g. Biochemical Society, Microbiology Society) and all PhD students can apply for financial support to attend national and international conferences. Annual Inspirational Speaker Days, organised by PGBio, help inspire ECRs to pursue a career in science (speakers included Sir Paul Nurse and Maria Leptin (Director of EMBO)). Both Research Days and Research seminar series include seminars from ECRs. Training for outreach and *MCE* outreach activities is provided locally (e.g. by supervisors and the *MCE* Director of Outreach), but also extends to support from both within and outside the University. PhD students are encouraged to identify mentors outside of their research supervisory team. Finally, in recent years we have initiated an opportunity to celebrate PhD awards, through an informal seminar and social event, and through highlighting in the PGBio Newsletter.

Our ECRs go on to a diverse range of careers, with a high proportion continuing to deliver impact; the generic skills training (e.g. numeracy and statistical competence, presentation skills, writing skills) available to them all ensures that all have a breadth of options. Thus, within the period, their destinations have included: academic research (e.g. Manchester MIB; WWU Münster), industry (e.g. Genomics England, Evonetix, LifeArc, Diamond light source, Isobionics, Liberty Produce) and other sectors (e.g. academic publishing; science communication consultancy; science funding agencies and charities). We have also recruited a small number of Clinical Research Fellows, who

often go on to prominent clinical positions (e.g. Colleypriest, now consultant gastroenterologist at the Royal United Hospital (Bath)).

Technical and Support Staff The University participates in a national 'Technician Commitment' initiative to support the visibility, recognition, career development and sustainability of technical staff. The UoA is supported by a team of specialist technicians, with representatives on the UoA Executive and Safety Committees.

Equality, Diversity and Inclusivity

EDI is embedded in the culture of the UoA, from being central to our staffing strategy to active promotion of EDI by a departmental EDI self-assessment team. Progress in EDI was recognized by an Athena SWAN Silver award in 2020. Most of our staff have dual career families with childcare commitments and engage with the Athena SWAN charter in the interests of a healthy work-life balance. Flexible/remote working is accessible to all staff, with 70% reporting having used this in our recent Athena SWAN survey. In addition to an emphasis on gender balance, Athena Swan has raised awareness in the UoA of all protected characteristics, increased transparency in all our processes and motivates our aim for a fairly distributed workload; anonymous staff surveys report that 80% of staff agree that the UoA is inclusive, with transparent policies for promotion, probation and career support. We have begun to monitor racial demographics, with BAME constituting 31% of PGR students and 11% of Academics/PDRAs (2019); we are working with HR to attract as diverse a pool of applicants as possible to our posts. A standard of agreed professional conduct has been developed with input and definition by professional services and agreed by the whole Department. Department positions, committee and panel members are appointed after an open and transparent call for expression of interest. All of our staff are made aware of unconscious bias and completion of a series of online EDI training courses is mandatory before taking part in recruitment, promotion, grant pitching, advisory and evaluating panels; disproportionate committee burdens for women in the UoA have been reduced by our improved gender ratio. Promotion criteria used to judge all cases are clearly defined. Transparency is equally important when awarding internal funds, with members external to the UoA helping judge applications where appropriate. Scientific excellence, learning outcomes and impact for career development are the main criteria used in these evaluations. Mental health and wellbeing are high priorities and we have worked closely with both Professional Services Staff and the University Chaplaincy to support staff and students. Staff have access to the Employee Assist Programme, while Student Services provide advice to staff supporting students. Social events help create a collegiate atmosphere and are organized at numerous levels within the UoA and University (from individual lab socials, to an annual Department Away Day), with inclusivity and cross-cultural sensitivity to the fore.

Specific examples of actions taken to support staff with varied protected characteristics during the REF period are diverse and individually tailored. Flexible working is available to all staff on request. Staff meetings and seminars are scheduled during core hours to accommodate staff with caring and other responsibilities. Staff returning from periods of sick leave are supported, e.g. through Occupational Health Counselling. Conference travel support has been provided for a colleague recovering from major health issues, whilst others have received financial support for visa applications for non-UK nationals to attend European Conferences. The UoA has a collegiate atmosphere, with those undergoing long periods of illness and rehabilitation actively supported, through continued visits, temporary supervision of research group and students, and a phased return to work, with accessibility support provided where necessary.

This REF submission has been prepared under the University's published Principles of Research Assessment and Management. Staff leading the REF process underwent specific EDI training and an extensive gender-balanced team has contributed to writing the Environment statement. Outputs and Impact Case Studies were selected by a representative team from the UoA, with attention paid solely to quality and impact of research.

3. Income infrastructure and facilities

Income

Research awards secured have increased by 93% in this REF period to >£30.9M (numbers are funds awarded throughout). Our strategy recognises the need for a diverse funding portfolio, including income from research councils (£19.5M, 64%), major charities (£5.5M, 18%) and industrial partners (£2.5M, 8%). In addition to the extensive support gained through early career awards (detailed below), major sponsors are the BBSRC (28%, 19 PIs) and MRC (22%, 18 PIs), with further funds from EPSRC (6%, 8 PIs), Wellcome Trust (5%, 6 PIs) and Leverhulme (5%, 2 PIs). Funding successes were spread across all of our research themes, and widely distributed across our academics.

There has been distinct success with international awards, including an ERC Advanced Award (Hurst €2.5M); an ERC Periscope consortium on Pertussis vaccinology (22 partners from academia and industry; €28M, of which £0.4M to Preston); joint BBSRC-São Paulo Research Foundation (FAPESP)-funded projects, one aiming to develop greener, cheaper fuels and chemicals from plant matter (Leak: £1.83M), and two on genetic architectures in evolution (Wolf: £855K); funding to understand environmental transmission of AMR (JPI-AMR, Feil €1.86M; MRC (AMR in a Global Context - Consortia Call Feb 2018) One Health Drivers of Antibacterial Resistance in Thailand £3M, Feil £744K).

Many projects are interdisciplinary, with cross-Department teams (and other partner institutions), e.g. with Civil Engineering (Gebhard EPSRC, total awarded £4.8M (UoA5, £0.6M), with Cardiff), Chemistry, Civil Engineering, Electrical and Electronic Engineering (Feil, EPSRC £1.1M (UoA5, £0.2M)), Mathematics (Kelsh BBSRC, £1.2M (UoA, £1M), with Surrey), Chemical Engineering and Chemistry (Leak/Henk/Crennell BBSRC-FAPESP, £1.5M (UoA5, £0.7M), with Imperial, Aberystwyth, and Brazilian partners), Mechanical Engineering and Chemical Engineering (Henk/Leak/Scott, EPSRC £3.2M (UoA £0.5M)).

In the charitable sector, CRUK Career Establishment and Pioneer Awards have driven Mason's peptide inhibitor research, and awards from Alzheimer's Research UK (Williams/Licchesi, Mason, van den Elsen), Bill and Melinda Gates Foundation (Beeching), British Heart Foundation (Bagby project grant and PhD studentship), Skin Cancer Research Fund (Vance) and BRACE (Mason/Williams/Subramanian/D.Brown) have been important in diversifying our research funding.

Core to our strategy is supporting early career academics gain research funding, with many acquiring early career grants and fellowships: e.g. Diezmann (Marie Curie Sklodovska Fellow, MRC and BBSRC New Investigator Grants), Cowley (Academy of Medical Sciences Springboard & Leverhulme), Walko (Academy of Medical Sciences Springboard & British Skin Foundation, BBSRC New Investigator), Taylor (Royal Society grant), and Nützmann (Royal Society grant), Gebhard (BBSRC and EPSRC) and Vance (BBSRC New Investigator).

Further income is generated from external use of our core facilities. Our recent investment into a new Genome Sequencing Facility generates income (>£113K 2017-2019) which funds the facility manager. Our Manduca facility is one of the world's premier resources, providing insects for toxicity studies and other research to companies and research laboratories in the UK, EU and globally (Israel, USA, Mexico, Paraguay, and China).

Underpinning our annual intake of about 20 PhD students/year (0.4/FTE/year) are studentships funded through diverse sources, including many DTPs involving collaboration with our GW4 (and other academic and industrial) partners:

- BBSRC Southwest Biosciences
- EPSRC Centre for Doctoral Training in Statistical Applied Mathematics
- MRC GW4 Biomed DTP
- NERC GW4+ DTP and GW4 FRESH CDT

- Evolution Education Trust PhD Studentships
- Other charities (e.g. Alzheimer's Society, ARF, ARUK, Bath Institute for Rheumatic Diseases, BRACE, MNDA, British Skin Foundation)
- Bath Alumni funds
- University of Bath University Research Studentship Awards, including those co-funded with external partners

Infrastructure and facilities

Biosciences was originally housed in one building, with a second completed just before this REF period. Through construction of the *MCE*, we now occupy a cluster of three large adjacent buildings. With a total floor space of >1700 m^2, the *MCE* has expanded the research space (nearly 370 m^2) and houses our **E&B** and some **I&I** theme members. The new building boasts state-of-the-art labs, and a meeting and outreach space designed to promote research creativity and communication of the excitement of research to a new generation. Support for our palaeontologists included a purpose-built fossil preparation and storage facility nearby. The *MCE* provides a new seminar room, meeting rooms and a social hub purpose-designed for outreach activities (see below) and for hosting national and international conferences. Other strategic investments have enhanced the support for neurosciences and developmental biology (animal facilities, microscopy), commercializing therapeutics, and through spin-out companies (Pudney, BLOC Laboratories). We additionally benefit from the cross-faculty bioprocessing facilities in Chemical Engineering and have access to facilities of industrial partners for antibody (UCB-Celltech) and vaccine production (GSK, Sienna; Birmex (GCRF) and Porton Biopharma).

Strategically, we identified bioinformatics/computing and bioimaging as two vital areas of investment. The recent establishment of the Isambard supercomputing network (£3M), an EPSRC/GW4/Met Office funded tier 2 high performance computing facility in collaboration with Cray, expands on and complements our in-house HPC facility Balena (£1M). This facility garnered international recognition as winner of the 2017 HPC Wire Readers' Choice Awards in both 'Best Use of HPC in Life Sciences' and 'Best HPC Collaboration in Academia, Government and Industry'. Further investment by this consortium to create Isambard 2, with double the capacity, has been announced this year and will ensure our ongoing competitiveness in this area. We co-lead the MRC CLIMB consortium (Co-I Sheppard £7.7M), providing cloud infrastructure for microbial bioinformatics. This has allowed the recruitment of a full-time facility manager of the associated sequencing facility who works closely with Sheppard on epidemiology and microbial evolution. Alumni and university investment has funded the construction of the new Tarr lab for bioinformatics (£200K), a front-end facility for multi-user server interface, further expanding our on-site genome analysis capacity.

Strategic investment (EPSRC, BBSRC, Wellcome Trust, plus University; £5.6M within period) by the Faculty has enhanced a facility (MC^2) bringing together state-of-the-art microscopy (TEM and SEM, Confocal, Multiphoton, and the new Light Sheet and hypoxia-imaging suite) and cell sorting (FACS) with our proteomics, mass spectrometry, and biophysical and chemical characterisation capabilities. This facilitates close collaboration between researchers and dedicated facility staff, enabling the rapid adoption of new technologies. Our suite of microscopy instruments has been expanded to include Light Sheet Microscopy, accommodated within the Bioscience cluster of buildings in space freed-up by the construction of the *MCE*. We benefit from embracing equal access to shared facilities of our GW4 partners. Of particular note are the distinctive imaging facilities at each partner institution, including the new state-of-the-art GW4 shared Cryo-Electron Microscopy facility (Wellcome Trust, £2.3M), located in Bristol. Co-applicant van den Elsen, is a member of the facility's steering committee. Local investment in CryoElectron Microscopy within MC^2 has provided a crucial feeder instrument for the GW4 high-end cryo-EM facility. Finally, UKRI-funded national facilities (including BBSRC synchrotron and Diamond light source (Harwell)), as well as international facilities (e.g. EMBL small-angle X-ray scattering facility, Hamburg) are widely utilised by our structural biologists.

The Biological Services Unit (contribution from UoA projects £0.75M (2014-2020)) provides outstanding facilities supported by a dedicated team of skilled animal technicians, for maintaining rodent and fish models underpinning *in vivo* research. Indeed, these facilities underpin ~15% of our research income. Recent investment (£135K) has doubled the size of our zebrafish facility and enabled the recent recruitment of Nikolaou, with a further recruitment in this area occurring just outside the REF period.

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

Collaborations, networks and partnerships (Fig. 1 and 2)

Research in Biosciences is vibrant, collaborative, and interdisciplinary, enabling the highest quality outputs and impact. In addition to numerous national collaborations, 63% of our REF outputs (up from 59% in REF2014) involve collaborators from outside the UK (data from Scopus). These collaborations involve partners at leading institutions throughout the world (e.g. EMBL, Max Planck and Pasteur Institutes, Stanford, UCSC, Nagoya, Melbourne and Stellenbosch)(Fig. 2). The **I&I** theme has links with major international consortia with access to samples from diverse locations, providing understanding of microbial relationships and the topography of a disease outbreak. For example, Sheppard is a core member of the CLIMB network (across >20 countries, e.g. Thailand, Gambia, Peru, USA, Australia) on pathogen genomics. Feil is the lead of SpARK, a JPI-AMR funded consortium with partners across UK, Italy, France and Norway and is a member of multiple international networks (SOLIDNESS, KLEBNet, OH-DART, ReNEW, EDGE) focussing on AMR. Likewise, in the **E&B** theme, collaborative networks are especially important for our behavioural ecologists. Szekely is a member of the B10k consortium that targets sequencing of all bird species, and manages Élvonal, a shorebird research network involving 14 countries (6 continents), focussing on uncovering the causes and implications of sex role behaviour. Focused networks linking internationally renowned researchers are prominent for those in 'omics and evolutionary theory areas, e.g. Nützmann's involvement in two EU COST Actions, and Wolf's ongoing projects with Brazil and USA examining multivariant quantitative genetics and the genetics of social evolution. Within the **MIB** theme, Leak leads a large BBSRC-FAPESP funded consortium of UK and Brazilian Universities, and Mason is a key member of the Australian Centre of Excellence for Innovations in Peptide and Protein Science network. In **CDB**, Williams contributes to a European network, ILSI Nutrition for the Ageing Brain. In a broader context, the COVID crisis presented an opportunity to build broad, research-based grass-root links with other universities; e.g. Universities for Science Consortium (Urrutia, founder) links Bath with 25 institutions in Mexico, USA, and Brazil, organizing international seminar series (live audiences of c 500; 5000 views). At a national Level, Gebhard provides the microbial component of a major interdisciplinary consortium (RM4L) looking at natural repair of damaged concrete structures (Cardiff, Cambridge, Bradford); Leak has been PI of, and CoI in numerous, multi-university interdisciplinary projects involving industry, with a focus on renewable resources and the circular economy. Many of our staff have been invited lecturers on advanced level international courses, e.g. Wolf (*Latin American School on Evolution*), van den Elsen (EMBL Hamburg, *Small Angle X-ray Scattering Course*), Williams (Montevideo, *4th Latin American School of Neurochemistry*).

Figure 2 Biosciences collaborative network extends worldwide

As well as these individual-dependent groupings, our researchers are prominent in a variety of open groupings. The GW4 Partnership between the key research institutions of SW England provide a natural opportunity for networking, often resulting in research collaborations. GW4 workshops focusing on AMR and Climate Change have developed into formal GW4 Strategic Alliances (Climate and AMR), the latter involving leadership from this UoA (Feil, Gebhard). Crucially, the GW4 partnership feeds into the various DTPs (BBSRC SWBio, MRC GW4 BioMed, NERC GW4^{+}), and brings a clear emphasis on collaborative teams, interdisciplinarity, and impact-focused activity.

Groupings around specific societal audiences have brought basic researchers, clinicians and patient groups into direct contact. For example, Departmental involvement in the Bristol and Bath Alzheimer's Research UK Network underpins our links to the GW4 Ageing and Dementia community, fostering collaborations within the region and providing a platform for outreach. Combined with membership of the ARUK GRB (Mason, Williams), it has significantly enhanced our visibility and reputation in the molecular basis of neurodegeneration. The *Cancer Research @ Bath Network* and the GenSoc-funded annual Mammalian Genetics and Development meetings achieve similar aims, bringing our researchers into contact with related academic and NHS specialists in Bath and beyond.

Finally, investment in diverse research centres provides the strongest strategic input into developing partnerships at a local level. Most prominent amongst these in this REF period has been the very substantial investment in the *MCE*, but other long-standing (e.g. *Centre for Mathematical Biology, Centre for Sustainable and Circular Technologies*) and new centres (e.g. *Centre for Therapeutic Innovations*, *Institute of Mathematical Innovation*) continue to play vital roles, providing the greatest opportunities to establish and support interdisciplinary research, as documented in Section 1 (p. 4) and Fig. 1.

These diverse networks enrich the research environment at all levels, e.g. building networks for ECR researchers, and invigorating our seminar series.

Contribution to the Research Base

Prizes, Awards and Fellowships The excellence and significant contribution of individual members of staff has been recognised externally through the award of fellowships and prizes. Hurst became both FRS and FMedSci, while Wonnacott is FBPS and Szekely is a foreign member

of the Hungarian Academy of Sciences, and was awarded the Hungarian Order of Merit. Szekely was awarded a Royal Society Wolfson Merit Award (£75K) and an ELVONAL Award from Hungarian government to elite research leaders (236M HuF). Subramanian was short-listed for an Asian Women of Achievement Award 2020. Younger staff and students have also received recognition with Cowley being awarded an Ebola Medal for Services in West Africa and also a junior award for Microbiology. Jones was invited to participate in the Rank Prize fund symposium (2020). Feil was recognised by ISI as being in Top 1% most highly cited in Microbiology (2015). Our students have also won prestigious prizes including Chinese Government Award for Outstanding Self-financed Students abroad (XianMing Wu, 2016), Sir Howard Dalton Young Microbiologist of the Year 2014 (Ali Hussein, First Prize), STEM for BRITAIN 2017 (Natalie Vaughan, Bronze Award), and Sir Kenneth Mather Prize for best PhD in UK in evolution (Rosina Savisaar, 2019). Hurst was awarded Paper of the Year by German Society for Stem Cells (2016). Research Fellowships were awarded to four members of staff, and an 1851 Fellowship to one further ECR. Hurst was awarded the Vice Chancellor's Research Medal (Bath, 2016). Ten academics have held 18 Visiting Professorships during the period, including at Universities of Cape Town (Acharya), Szeged (Hurst), Chang Mai (Sheppard), Debrecen, Groningen, and Berlin Institute of Advanced Studies (Szekely).

Learned societies and Government agencies Eighteen staff have occupied major roles within 17 national and international learned societies/government agencies. As President of the Genetics Society, Hurst joins an impressive rollcall of such Presidents (e.g. Haldane), and served on the Royal Society's FRS Appointment Committee. Sheppard was chair of Genetics Division of UK Microbiology Society. Acharya served on the Royal Society's Equality and Diversity Panel. Wolf is an invited nominator for the Kyoto Prize. As part of the UK's COVID response, Cowley has been seconded as an Embedded Scientist to the International Comparisons Joint Unit, within the COVID-19 Taskforce at the Cabinet Office.

Journal editorships and editorial board memberships All staff contribute through refereeing of academic publications and/or research proposals. More significantly, 28 staff have been members of the editorial boards of *c.* 60 journals (including *PLoS Biology, Genome Biology & Evolution, Trends in Genetics* (Hurst)), with 9 staff having held journal editor positions (e.g. Wonnacott, Editor at *British J. Pharmacology*; Sheppard as Deputy/Acting Editor-in-Chief, *Microbial Genomics*; Leak, Managing Editor at *Biocatalysis and Biotransformation*).

Grant funding panels and institutional reviews We are widely involved in national (including BBSRC (9 individuals), MRC (5), NERC (2), EPSRC, NC3Rs, Royal Society, Wellcome) and international funding committees (e.g. ERC) (30 staff, some sit on multiple panels). Of particular note, Hurst sits on the Royal Society URF and the Academy of Medical Sciences AMS Springboard panels. Our academics have assisted with institutional reviews, e.g. quinquennial reviews of the Mammalian Genetics Unit (Harwell) and the Stem Cell Institute (Edinburgh)(Ward), mid-term reviews for both Pirbright and Babraham Institutes (Wonnacott), and review of Epigenetics Section of MRC London Institute of Medical Sciences (Murrell).

Conferences and seminars Our academics organised a total of 45 major national and international conferences during the period, in addition to organising/chairing 75 sessions. We gave 209 invited talks and 47 plenary talks at conferences. In total, therefore, we gave on average 5.5 conference talks/FTE, indicating the scale and reach of our academics. Hurst helped organise Royal Society Fellows conference (2016). Our academics have given >215 seminars at institutions across UK and the world (including Universities of Cambridge, Edinburgh, Vienna, Zurich, Columbia, Texas A&M, Wisconsin-Madison, Toronto, Beijing, Brisbane, and at Max Planck and Pasteur Institutes, The Jackson Laboratory, and Institute for Advanced Study (Berlin)).

ECR training makes a major contribution to the research base with our students and PDRAs being sought-after, going on to contribute in many science-related areas, as noted in Section 2 (p. 11). In this way, they make an expansive contribution to the research community and wider economy. Our staff also contribute to training of PhD students in other institutions (e.g. 110 PhD vivas as external examiners).

Research reproducibility is an important consideration in all our research, but sometimes forms the specific focus. A prime example is a study comparing 23 laboratory strains of *Campylobacter jejuni* that identified the effect of even small genomic differences on the validity and reproducibility of experimental work (Sheppard: *Microbial Genomics*). Our academics also use their editorial positions to provide a platform for promoting reproducibility (e.g. Wonnacott: *Brit. J. Pharmacology*). Finally, a key impact of the CiteAb impact case (Chalmers) is reproducibility of research using antibodies.

Contributions to the Economy

Wealth generation is a hallmark of successful bioscience research, and UoA staff work closely with industry and national agencies in response to national and international priorities/initiatives, through grant (e.g. Innovate, IB Catalyst, EPSRC Sustainable Feedstocks, NIBB) or direct funding and CASE studentships (see section 1, p. 5). As a result, 9 staff have sought patent protection (13 applications) within the REF period, on IP resulting from their research, ranging from a methodology for extracting naïve human stem cells (Hurst), through to protein structure analysis (Pudney). Some of this IP has been successfully licensed (e.g. van den Elsen licensed glycation detection kit to Abcam, Kerafast and Ximbio) or developed via a spin-out company (e.g. Pudney established BLOC Laboratories Ltd, for rapid assessment of protein stability and dynamics). Chalmers established CiteAb, a company based on an antibody search engine, to which (following a part-time arrangement) he has recently moved full-time. The latter has become the primary source of information on antibody reagents (see *Impact Case Study*). Sapience Therapeutics Ltd is applying Mason's peptide-based inhibitors technology to develop therapeutics for difficult-to-treat cancers (see *Impact Case Study*). At an organisational level, Leak was Director of P2P, a BBSRC sponsored national Network in Biotechnology and Bioenergy which fostered Industry-Academic network development and funded partnerships through business interaction and proof of concept awards. P2P produced the scoping report "Building UK-Africa Partnerships in Industrial Biotechnology and Bioenergy" which formed a cornerstone in the 2018 GCRF call for developing partnerships in IB in developing countries.

Several of our staff have contributed to activities supporting international development, benefiting both the local and national economy, and working alongside local partners. Notably, Szekely is Founder and Chairman of the Maio Biodiversity Foundation which supports conservation, biological research and development of employment through Eco-Tourism in Maio, Cape Verde (see *Impact Case Study*). Cooper was instrumental in developing and applying control measures for fungal disease of oil palm in Malaysia and Africa, while Scott and Beeching were executive board members of Crop Innovations, supporting improvements in agriculture with a focus on international development.

Contributions to Society

Many of our staff have been making significant contributions to society in general through their ancillary "community service" activities (e.g. school visits, workshops for teachers), and through focused outreach activities that together help both broaden the public's understanding and 'personalise' our research to our communities. At a national (and, increasingly, international) policy level, the example of Perry is outstanding in illustrating the recognised expertise of Bioscience academics. Perry's expertise on the editing of mammalian genomes resulted in invitations to sit on key expert panels, including Human Fertilisation & Embryology Authority (HFEA), leading to an extensive series of public engagement and public policy activities, ranging from House of Lords addresses to television and radio interviews (CNN, Fox, BBC, see *Impact Case Study*). Jones was involved in the Wellcome Trust and Department of Health working party on alternatives to antibiotics. Others whose work has led to media engagement include Danson (Discovery Channel; Life on Mars), van den Elsen (BBC Country File; TB vaccine), Gebhard (Discovery Europe; self-healing concrete), and Laabei (Daily Mail, BBC Radio; Cigarette smoke and emergence of multi-drug resistant superbugs). In addition, Biosciences staff are active in contributing to a series of online articles, *TED-Ed Talks, Conversation*, *The Spectator* covering topical issues, especially in Evolution (Hurst, Kover, Longrich, Priest, Wills) and epidemiology (Feil). These articles (averaging 10-15 a year) have achieved impressive reach, with in excess of four million downloads to date,

and Hurst's TED-Ed animation on human evolution has had >1.0 million views. In response to COVID, the *MCE* sponsored a COVID-focused *GeneticShambles* (https://cosmicshambles.com/geneticsshambles), Hurst redirected part of his ERC funding to studying mutation patterns in SARS-COV-2 (*Mol. Biol. Evolution*), and Feil and Preston have carried out regular, at times daily, science communication work on local and national Radio and TV during the COVID crisis, including a regular, biweekly slot on Radio Bristol since March 2020 (Feil), and >150 media interviews (Preston).

We actively collaborate with the University Press Office and the Public Engagement Unit to deliver extensive outreach and public engagement activities. Three regional public outreach events are regularly attended by staff across all Themes. *Bath Taps into Science* is a week-long public event. attracting thousands of visitors every year. It focuses on enthusing school children and families about the world around us and the research performed at the University. The *Bath Science Cafe* programme (Scott/Priest**)**, has provided a stimulating, informal opportunity for the public to gain detailed understanding of research within the biosciences community. Our researchers contribute regularly to the national *A Pint of Science* and *Festival of Nature* events. These events provide a platform for engaging with a diverse audience and stimulating interest among sectors traditionally disinterested in science. Our dynamic program of press releases averages two billion reach per annum with an advertising costs equivalent of approximately £20M. We have won two awards from the Genetics Society for our outreach and were runner up for the Guardian Marketing and Comms Award.

Key in our societal engagement portfolio is the work done by members of our **E&B** and **I&I** themes organised through the *MCE*. The *MCE* has such outreach as one of its founding principles, has a dedicated Outreach Officer, and has made numerous wide-ranging contributions nationally and internationally. One of the *MCE*'s research focuses is the pedagogy of teaching evolution in both formal (school) and informal environments, funded by a dedicated PhD programme, with 2 PhDs completed, 1 current PhD and funding for 4 more secured. The *MCE* building was designed to host primary school visits for evolution-based outreach activities; to date over 200 school children have visited. Our MOOCs, facilitated by FutureLearn and endorsed by UK National STEM Centre, have gained significant international reach. The MOOC *Understanding and Teaching Evolution* (three runs to date, reaching 3,101 participants world-wide. The MOOC *Inside Cancer: How Genes Influence Cancer Development* (19 runs since 2014 with nearly 51,549 enrolments from >150 countries) represents a research by cancer researchers, clinical oncologists and teaching fellows from the UoA and Royal United Hospital in Bath, enabling the general public to better understand the challenges and opportunities in cancer therapy.

In summary, academics within this UoA play a major role in Biosciences research, both within the UK and internationally, as demonstrated by the quantity and quality of their publications, their funding and the recognition they have received. With substantially increased investment over the REF period, a supportive community and a focus on some of the most important questions and challenges in our fields, we are well-placed to maintain and build on that success into the future.