

Unit-level environment template (REF5b)

Institution: University of East Anglia

Unit of assessment: UoA5 (Biological Sciences)

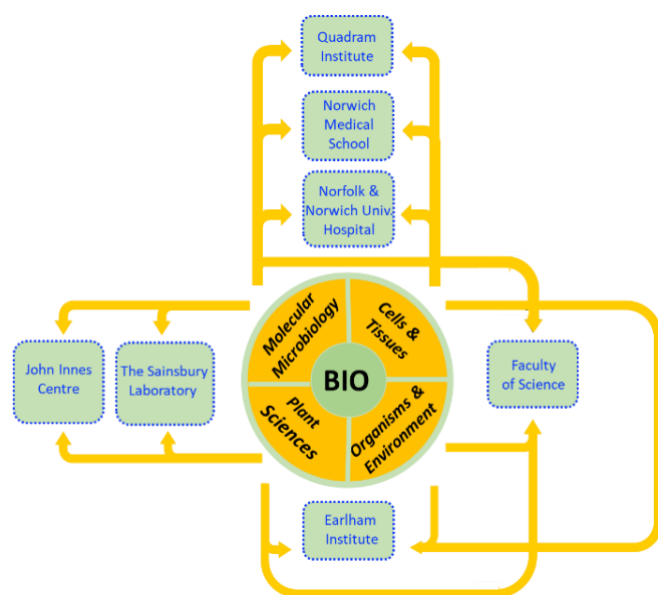
1. Unit context and structure, research and impact strategy

1.1 Introduction to the unit, including context and structure

Our UoA5 return comprises the research and impact of 75 staff employed by the University of East Anglia (UEA) and working within the biological sciences. The majority are based in the School of Biological Sciences (BIO) and other staff are based in the Norwich Medical School and neighbouring partner institutes – Earlham Institute, John Innes Centre, Quadram Institute and The Sainsbury Laboratory. Along with the Norfolk and Norwich University Hospital, all these lie on the Norwich Research Park, an extended campus containing one of the Europe's largest concentrations of researchers in the life sciences. Though just under 60 years old, the School has produced two winners of the Nobel Prize in Physiology or Medicine (2001: Sir Paul Nurse, PhD 1973; 2020: Professor Michael Houghton, BSc 1972). We are especially proud that Professor Sarah Gilbert, who led the team that developed the Oxford-AstraZeneca COVID-19 vaccine, is a graduate of the School (BSc 1983). The unit's current staff include three Fellows of the Royal Society and 3-5 staff have been among the top 1% most highly-cited researchers worldwide each year in the four years to 2020.

The unit structures its research into four overarching research themes: *Cells & Tissues*, *Molecular Microbiology*, *Organisms & Environment* and *Plant Sciences* (see figure at right). The majority of staff in *Plant Sciences* are in The Sainsbury Laboratory, a research institute with its own funding and governance co-founded by UEA. Within the unit, the School is part of UEA's Faculty of Science, enjoying excellent collaborative relationships with its sister Schools, particularly the Schools of Chemistry and Environmental Sciences. Via the shared Biomedical Research Centre, it has a close relationship with the Norwich Medical School in the Faculty of Medicine and Health Sciences. Staff in the unit contribute to several virtual research centres, including the Centre for Ecology, Evolution and Conservation (linking to the School of Environmental Sciences), the Centre for Molecular and Structural Biochemistry (linking to the School of Chemistry), the Earth and Life Systems Alliance (linking to the John Innes Centre and other Norwich Research Park institutes) and the Norwich Institute of Healthy Ageing (linking to the Norwich Medical School). The School is housed in a single building, adjacent to the Biomedical Research Centre and continuous with the other Science Schools, so facilitating collaborations. All components of the unit lie within 15 minutes' walk of one another on the Norwich Research Park.

The School has built a successful research community by following a strategy combining the pursuit of research excellence across the biological sciences with a focus on particular areas of strength and collaboration within the unit and beyond. Across the four research themes, we take



Thematic structure of the unit, with some of the principal Norwich Research Park links.
BIO: School of Biological Sciences.

an integrated approach, connecting biology at all scales, from molecules, genes and genomes to populations and ecological communities. We work on fundamental biological mechanisms and processes using state-of-the-art tools and approaches, with emphasis on developmental biology, biomedical research to elucidate health and disease, microbiology, evolutionary biology, ecology, conservation, molecular biology and plant sciences. Work from all our themes achieves strong impact, and we value our excellent industrial links. Our ideal is a unit whose success rests on a strategy that encourages research excellence, impactful science, fruitful synergies and a supportive and diverse culture, as well as capitalising on the unit's central place within the Norwich Research Park. For this reason, we pride ourselves on our activities and events promoting internal communication, esprit de corps, mutual respect and wellbeing. These include daily use of a social space/café at the core of the School (the BIO Atrium), weekly Friday evening social gathering, Head of School's weekly 'good news' message, monthly staff meetings, prizes for best colloquium talk and poster by Contract Research Staff and PGR students, summer barbecue, Christmas party and sports events.

Through strategic growth, income generation and expansion, the unit has grown substantially since the REF2014 assessment period. Specifically, through new appointments, the School has gained six academic research staff and The Sainsbury Laboratory has gained a group leader, making a net increase of seven staff. At the same time, the unit's submission has expanded to include newly-appointed staff in the Norwich Research Park institutes and independent researchers, bringing it to its current size of 75 staff (by contrast, 44 staff were returned in REF2014). Over the assessment period, the unit's HESA-reportable research income was £65.6M. The unit produced over 1,270 outputs, which have collectively been cited (in Web of Science) over 31,850 times. They include 109 research outputs published in highly competitive, multidisciplinary venues (16 *Nature*, 25 *Nature Communications*, 28 *PNAS*, 11 *Science*) or subject-specific venues (4 *Cell*, 25 *Nature* subject journals).

Highlights among the unit's achievements in the assessment period include:

- Outstanding research discoveries across all four research themes, a selection of which are showcased in Box 1.1.
- Seven successful ERC grant applications (two Advanced, four Consolidator and one Starting Grants).
- Eight successful independent research fellowship applications/transfers (four BBSRC Future Leader, two NERC Independent Research, one Royal Society Dorothy Hodgkin and one UKRI Future Leaders Fellowships).
- Four successful Doctoral Training Partnership (DTP) applications, i.e. from BBSRC (Norwich Research Park DTPs 1 and 2), NERC (ARIES DTP) and the Wellcome Trust (EDESIA DTP), leading to continuous DTP funding to the unit throughout the assessment period.
- Substantial increase in the number of internally registered Impact Case Studies (15 to 28 cases), with five of our six submitted cases being new, including one based on the spin-out company NatureMetrics co-founded by Yu in 2016 and valued at £7.5M by 2019.
- Appointment of a Royal Society-funded Entrepreneur-in-Residence to help sustain our impact agenda.
- Award to the School of Athena SWAN Silver status in 2017, replacing Bronze status held from 2013.

Box 1.1 Selected research discoveries of the unit (collectively cited >1000 times on Web of Science).

Cells & Tissues Theme

- **Haerty** developed a new bioinformatic approach to characterise a psychiatric risk gene in human brain (2020. *Molecular Psychiatry*; DOI: 10.1038/s41380-019-0583-1).

- **Münsterberg** discovered a role for bone morphogenetic proteins in heart formation in chicken embryos (2014. *PNAS*; DOI: 10.1073/pnas.1321764111).
- **Rushworth** showed how transfer of mitochondria to blood stem cells aids rapid response to infection in mammals (2019. *PNAS*; DOI: 10.1073/pnas.1913278116).
- **Williams** identified signalling pathways underpinning tissue renewal in the lining of human colon (2014. *Gut*; DOI:10.1136/gutjnl-2012-304067).

Molecular Microbiology Theme

- **Clarke** characterised a protein complex acting as a transmembrane molecular wire in bacteria (2020. *Cell*; DOI: 10.1016/j.cell.2020.03.032).
- **Crombie** described the mechanism by which a bacterium assimilates short-chain alkanes and methane, a key climate change gas (2014. *Nature*; DOI: 10.1038/nature13192).
- **Hutchings** identified antimicrobial metabolites produced by a fungal parasite of ants, suggesting a novel source of antibiotics (2018. *Nature Communications*; DOI: 10.1038/s41467-018-04520-1).
- **Kingsley** showed how within-host genomic evolution affects host adaptation by *Salmonella* (2016. *Nature Microbiology*; DOI: 10.1038/nmicrobiol.2015.23).
- **Todd** showed that marine bacteria produce dimethylsulfoniopropionate (DMSP), the major precursor of the climate change molecule dimethyl sulfide (DMS), and identified the first DMSP synthesis gene (2017. *Nature Microbiology*; DOI: 10.1038/nmicrobiol.2017.9).

Organisms & Environment Theme

- **Gage** demonstrated a novel effect of Darwinian sexual selection in protecting animal populations from extinction (2014. *Nature*; DOI: 10.1038/nature14419).
- **Immler** experimentally demonstrated in a vertebrate that maintaining the germline is costly, a key tenet of the evolutionary theory of ageing (2020. *PNAS*; DOI: 10.1073/pnas.1918205117).
- **Richardson** showed that cooperatively-breeding birds exhibit delayed senescence, demonstrating links between sociality and ageing in animals (2019. *Nature Communications*; DOI: 10.1038/s41467-019-09229-3).
- **Spurgin** demonstrated the presence at the genomic level of natural selection on beak length in a wild bird (2019. *Science*; DOI: 10.1126/science.aal3298).

Plant Sciences Theme

- **Balk** identified a molecular mechanism preventing the excess uptake of iron by plant roots and leaves (2019. *PNAS*; DOI: 10.1073/pnas.1907971116).
- **Dalmay** showed that small RNAs regulate flower pigmentation and help maintain flower colour diversity (2017. *Science*; DOI: 10.1126/science.aao3526).
- **Hobbs** (formerly Ryder) and **Talbot** identified a turgor-sensing kinase that enables the rice blast fungus to penetrate the host plant's leaf surface (2019. *Nature*; DOI: 10.1038/s41586-019-1637-x).
- **Jones** demonstrated that some plant immune receptors incorporate a 'decoy' protein domain enabling them to detect pathogenic bacterial effector molecules targeting that domain (2015. *Cell*; DOI: 10.1016/j.cell.2015.04.024).
- **Kamoun** showed that small differences in the effector molecules of the pathogen lineage including the potato blight organism allow new host species to be attacked (2014. *Science*; DOI: 10.1126/science.1246300).
- **Zipfel** elucidated the role of receptor kinase in mediating plant immune signalling (2017. *Science*; DOI: 10.1126/science.aal2541).

1.2 Research and impact strategy, with review of past and future objectives*Overview and strategy*

The unit's current research and impact strategy was constructed via a formal review led by the Pro-Vice Chancellor for Research & Innovation, which involved an assessment of the draft strategy and extensive consultation by the PVC's team, followed by a unit response and final recommendations. Progress in implementing the strategy is monitored annually by the School and the Faculty of Science's Associate Dean of Research. Our core strategy and values are presented in Box 1.2, and our forward strategy is presented further below ('*Strategic research objectives over the next five years*').

Box 1.2 Unit's core research and impact strategy and valuesCore research and impact strategy:

- To pursue world-leading excellence in research and impact across the four research themes.
- To support and grow areas of strength within the themes while remaining flexible in response to opportunities arising and to changing research and impact needs.
- To continue to grow our collaborations across the University and beyond, including capitalising on our position within the Norwich Research Park.
- To respond to regional, national and international research priorities.
- To pursue a staffing strategy of recruiting outstanding new staff, including independent fellowship awardees/holders, and to support the ongoing career development of both new and existing staff.
- To provide excellent training for the next generation of researchers in our PGR programmes.
- To deliver excellent research-led masters and undergraduate teaching.

Values:

- We ensure that all our activities meet the highest standards of equality and diversity.
- We hold ourselves to exemplary standards of research integrity.
- We promote open research and data sharing.
- We contribute our professional expertise and services to the research community.
- We communicate our science to as wide an audience as possible.

The evidence for the success of our strategy in enhancing the vitality and sustainability of the unit is presented in our REF2021 submission as a whole and herein. We promote continued vitality and sustainability through encouraging, supporting and valuing research and impact as integral components of the unit's activity at every level.

Review of implementation of unit's research plans from REF2014

Within our overall strategy (core plus forward strategy), our REF2014 objectives were: "*targeted, selective growth in each Theme by appointing high calibre researchers and post-graduate PhD students, and by contributing to Norwich Research Park strategy in five areas covering biodiversity, food security, synthetic biology, industrial biotechnology/bioenergy, and gut health.*"

The unit has met and indeed exceeded these objectives. A total of 24 new academic research staff have been appointed, including 15 new staff in the School. In the same period, 9 staff left the School (for retirement, new UEA posts or new external posts), leading to growth from 45 to 51 staff, i.e., an increase of 6 staff for the School across all four research themes (Section 2.1). Similarly, PhD student numbers have grown steadily over the assessment period (Section 2.2). The School appointments included staff in the targeted areas of biodiversity (**Spurgin, Suh**),

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food security (**Dicks**), synthetic biology (**Miller**) and industrial biotechnology/bioenergy (**Lea-Smith**). The exception was gut health, but we achieved this objective by the strategic transfer of **Robinson** to a group leader position at the Quadram Institute, a premier setting for the field. In addition, **Moxon** was appointed to meet an emerging need to build our strength in bioinformatics.

In REF2014, the unit also defined six specific strategic objectives, and each of these has also been met (Table 1.1).

REF2014 objective	REF2021 fulfilment
1. "Appoint new researchers ... in the areas of food security, agri-intensification, ecosystem services and conservation biology."	✓ Appointments of Dicks and Spurgin .
2. "Develop our expertise in molecular ecology and marine microbiology for understanding sustainability in the oceans, in collaboration with nearby CEFAS [Centre for Environment, Fisheries and Aquaculture Science, Lowestoft] in fisheries research."	✓ Appointments of Immler and Lea-Smith ; co-supervision of three PhD studentships with CEFAS (Taylor).
3. "Create a base for translational medical research in the new Medical Research Building, in collaboration with the Norwich Medical School and the NNUH."	✓ Contribution to Quadram Institute, a new institute on the Norwich Research Park, created in a partnership of BBSRC, the Norfolk and Norwich University Hospital and UEA, dedicated to translational medical research, especially in areas of diet and health, gut biology and microbiology; including transfer of Robinson to group leader position.
4. "Contribute in areas of diet and health, gut biology and microbiology, involving creation of a new Norwich Research Park Institute, The Centre of Food, Health and the Gut."	
5. "Participate with other UEA Schools (Mathematics, Environmental Science, Computing, Chemistry) in the formation of the research platform of the new School of Engineering, whose portfolio of research will embrace microbial systems for energy capture."	✓ Development of UEA's new School of Engineering, which in 2019 won major funding of £4.5M from the New Anglia Local Enterprise Partnership for Norfolk and Suffolk to create, aided by UEA investment, Productivity East, a new regional hub for engineering, technology and management.
6. "Recruit a synthetic biologist to metabolically engineer cells to yield useful products, such as biofuels and anti-infective agents, as part of a new Eastern Academic Research Consortium (ARC) involving UEA and the Universities of Essex and Kent."	✓ Appointment of Miller as the Eastern ARC Research Fellow in Synthetic Biology, in collaboration with the other universities in Eastern ARC.

Strategic research objectives over the next five years

As evidenced by the unit's progress and achievements, our core strategy (Box 1.2) of combining a focus on areas of strength with the flexibility to respond to changing priorities has served us well. We will therefore continue to implement it, with renewed emphasis on harnessing the benefits of our position within the Norwich Research Park. These have included our successful BBSRC and EDESIA DTP bids (Section 2.2), access to and bids for large-scale capital equipment and infrastructure (Section 3.3) and much of our collaborative and interdisciplinary

work (Sections 4.1, 4.4). Specifically, within the overall strategy, over the next five years we intend to:

- Aided by state-of-the-art research tools and infrastructure, grow our activity within each theme in research areas addressing grand challenges in health, biodiversity, climate, energy and food security, in particular:
 - Fundamental causes of disease, e.g. arthritis and cancer, and contributions of dietary factors to disease and ageing (*Cells & Tissues*).
 - Evolutionary origin and maintenance of biodiversity, as well as its ecological determinants and conservation; and the role of genomic and epigenetic factors in determining phenotypes (*Organisms & Environment; Plant Sciences*).
 - Role of microbes in global climate (*Molecular Microbiology*).
 - Extraction of energy from microbes (*Molecular Microbiology*).
 - The molecular basis of crop plant pathology (*Plant Sciences*).
- Continue to address the massive growth in the availability of sequence data through consolidating our expertise in bioinformatics.
- Broaden and deepen our commitment to impact generation and our growing impact portfolio.
- Leverage our position within the Norwich Research Park to continue to make full use of its complementary expertise, facilities and critical mass, especially in collaboration with the Norfolk and Norwich University Hospital and the new Quadram Institute; likewise, grow our collaborations within UEA, especially with Productivity East.
- Address regional and national research priorities, as well as international priorities through increasing engagement with the goals of GCRF.
- Continue to strive for best practice in equality and diversity, and specifically to renew our Athena SWAN Silver status and then apply for Gold status.

Implementation of this forward strategy will be led by the Head of School (currently **Dalmay**), Director of Research (currently **Bourke**) and Director of Innovation (currently **Brearley**). Progress will be assured via our established means of annual review of achievements against milestones and timelines as reported by the School to the Faculty of Science's Associate Dean of Research, followed by readjustments as required.

1.3 Impact: strategic goals, mechanisms and achievements

Within the unit's overall strategy, the central goal with respect to impact has been to achieve, over the assessment period, a complete culture change. Led by our Directors of Innovation, we aimed for impact to become recognised as an integral component of our activities. We have achieved this through implementing the strategy via a variety of mechanisms and approaches (Sections 2.1, 3.1). Evidence of our success is found in:

- Our number of internally registered impact cases almost doubling (15 to 28 cases).
- Our impact income showing a healthy vitality, whether through paid consultancies, external partner contributions to CASE/iCASE PhD studentships or awards from internal UEA funds (Section 3.2).
- Impact growing across multiple sectors, including Agricultural/Food Security (e.g. **Brearley, Dicks, Jones, Talbot**), Biomedical (**Clark, Gavrilovic, Wormstone**), Environmental (**Bell, Bourke, Butler, Dicks, Gill, Lehtovirta-Morley, Yu**) and Pharmaceutical (**Chantry, Fountain**) (Section 4.2).
- Five of our six Impact Case Studies submitted to REF2021 being new and all six (led by Baulcombe, **Bourke & Dicks, Brearley, Jones, Wormstone** and **Yu**) having been developed through the mechanisms that were established (Sections 2.1, 3.2).
- Leads of the submitted cases each being previous winners in the annual UEA Innovation and Impact Awards contest, 2018 (**Brearley** and **Wormstone** in the category, Consultancy Project of the Year, and **Yu** in the category, Outstanding Commercialisation of Technology).

Looking forward, we will continue to pursue our strategy to nurture our growing portfolio of active impact cases, thereby assuring the future vitality and sustainability of the unit's impact.

[1.4 Unit's approach to interdisciplinary research](#)

The unit embraces interdisciplinary research whenever solving research questions requires the combined approaches of several disciplines. Features and mechanisms facilitating interdisciplinary research are as follows (with outcomes detailed in Section 4.4):

- The Biomedical Research Centre, co-founded by the School and the Norwich Medical School expressly to promote interdisciplinary approaches to human disease and, via links with the Norfolk and Norwich University Hospital, translation to the clinic. Physically connected to the School, it hosts up to 20 group leaders from across the School, the Norwich Medical School and the School of Pharmacy. We maintain a dynamic presence, with four new appointments establishing their laboratories in the centre in the assessment period (**Akay, Griffin, Monk and Rana**).
- The Quadram Institute, opened in 2018 and now housing approximately 300 staff, providing a new partner for the unit's biomedical research, focused on diet and health. In 2018 **Robinson** transferred from the School to a group leader position in the Institute and in 2019 the School and the Institute held a 'speed-dating' event specifically to promote interdisciplinary collaboration.
- Links across the Norwich Research Park cemented through: two School staff in tailor-made 'Synergy Posts' based in the John Innes Centre (**Balk and Malone**); new unit staff appointed in the Earlham Institute and Quadram Institute; and the unit's membership of the across-Norwich Research Park virtual research centres (Section 1.1).
- The Norwich Research Park Science Links Seed Fund, providing up to £15K for projects initiating collaborations between researchers at two or more institutes on the Park, with an emphasis on interdisciplinarity.
- Four DTPs held across the unit, other Norwich Research Park institutes and external partners (Section 2.2), again actively promoting interdisciplinarity by encouraging across-institution PhD project applications.

[1.5 Progress towards an open research environment and reproducibility](#)

The unit pursues open research and reproducibility through both University-level processes (REF5a) and unit-level actions. For example, all outputs are uploaded as accepted manuscripts to the Pure research information system for external accessibility in compliance with REF open access requirements. A new UEA initiative will extend open access to datasets, so facilitating reproducibility. The University also disburses UKRI and charity funds to pay for open access publication in accordance with funders' requirements. The unit has gone above and beyond these requirements in several ways. In our REF submission, 97% of in-scope outputs are open access-compliant, exceeding the 95% threshold. These outputs include ones testing reproducibility, with **Chapman** having shown that an influential study claiming an effect of the gut microbiome on reproductive isolation in insects was not reproducible (2017. *PNAS*; DOI: 10.1073/pnas.1708345114). The unit was also an active participant in UEA's Open Access Week in 2018. Unit staff routinely post their data and data analysis code in public repositories, and our PGR student inductions train the next generation of researchers in the need for open research and reproducibility.

[1.6 Research integrity and ethics](#)

UEA is a signatory of the revised 2019 Universities UK Concordat to Support Research Integrity and the Concordat on Openness in Animal Research, and all staff are held to UEA's Research Ethics Policy. At unit level, we have again gone above and beyond to instil exemplary research integrity standards. For example, revisions to UEA's Research Ethics Policy are highlighted in the monthly research newsletter circulated by the Director of Research (**Bourke**). Unit member **Riley** chairs UEA's proactive Animal Welfare and Ethical Review Board. Reinforcing this,

Bourke, Riley and staff from the University's Research and Innovation Services ran two Research Ethics workshops for staff during the assessment period. Lastly, as for open research, our inductions train new staff and PGR students in the paramount importance of research integrity and ethics.

2. People

2.1 Staffing strategy and staff development

Within the unit's overall strategy (Sections 1.2, 1.3), our staffing strategy is to facilitate career development at every level and to recruit outstanding new staff in open, fair competition and then support them from the start of their appointments. This includes attracting independent fellowship holders and mentoring internal and external applicants for fellowships to be hosted by the unit, and providing excellent training and career support for our PGR students. For all, we seek to provide a research environment with the highest standards of equality and diversity.

Staff development strategy

To implement our strategy, we deploy a suite of mechanisms at University, Faculty and School levels:

- *Annual appraisal:* For academic research staff, annual appraisal is by a single, senior team comprising the Head of School, Director of Research and Director of Learning and Teaching. Appraisal is a supportive process and, as well as including University-mandated Research Activity Planning focused on research and impact, covers workload, training needs, promotion guidance and work-life balance. For Contract Research Staff, appraisal is by the Principal Investigator (PI), with additional appraisers nominated by the appraisee present on request, and includes training needs and optimising career development for further employment. If required, Contract Research Staff are pointed to the Faculty of Science's Bridging Fund, which provides bridging salaries for up to three months.
- *Training and continuing professional development:* These are delivered by UEA's Centre for Staff and Educational Development, which includes over 200 courses and is open to all UEA employees and PGR students. Its individual development funding scheme provides funding for additional off-site or specialised training.
- *Concordat to Support the Career Development of Researchers:* PIs follow UEA's Code of Practice for the Management of Research Staff, now informed by the revised Concordat. UEA has also developed a Concordat Implementation Plan to fulfil the Concordat's goals (REF5a). For example, it offers financial relocation assistance to new Contract Research Staff and provides top-up funds for merit-based promotions and salary progression awards.
- *Promotions:* The School's Promotions Committee, whose 14 members include the Directors of Research, Innovation and PGR, considers confirmation of appointment and promotion for academic and Contract Research Staff in accordance with UEA's promotion processes. The Committee assists applicants as fully as possible. Before each meeting, it circulates 'benchmarks' that provide anonymised examples of research and impact achievements in previous cases of successful promotion, and Committee member **Chapman** informally advises applicants as Promotions Mentor. After each meeting, the Committee provides every applicant with constructive written feedback.

Staffing and recruitment policy

To implement our strategy of recruiting outstanding new staff in open, fair competition, all UEA staff sitting on recruitment panels undergo mandatory Recruitment & Selection training and all staff undergo Diversity in the Workplace training, each refreshed every 2-3 years. Similarly, the School has introduced 'bias interrupters' to scrutinise each step during recruitment for Unconscious Bias. Recruitment is by external advertisement to meet a defined need. We also issue regular calls for applications for independent research fellowships to be hosted in the unit.

In the assessment period, there were 24 new staff appointments, consisting of 15 appointments to the School, along with five new group leaders in the Earlham Institute, two in the Quadram Institute and two in The Sainsbury Laboratory. Appointments to academic research staff positions are generally indefinite subject to confirmation of appointment (after a probation of up to five years). Across all such staff in the unit on the census date, all were either on indefinite contracts (89%), on probation (8%) or on fixed-term contracts (3%) prior to completing moves to other institutions.

Evidencing the success of our strategy to attract fellowship awardees/holders and underscoring the unit's attractiveness to high-quality researchers, five academic appointments in the School were of independent research fellows funded by competitive and prestigious schemes (total value £2.87M). Three staff won new fellowships (**Akay**, UKRI Future Leaders Fellowship; **Dicks**, NERC Independent Research Fellowship; **Spurgin**, BBSRC Future Leader Fellowship) and two transferred their fellowships from other HEIs (**Lehtovirta-Morley**, Royal Society Dorothy Hodgkin Fellowship; **Perry**, NERC Independent Research Fellowship). In addition, **Ding**, Monaghan and Pennington each won a BBSRC Future Leaders Fellowship held in The Sainsbury Laboratory. All independent research fellowship holders in the School were appointed proleptically as indefinite posts (subject to probation). Hence the School is set to maintain its 100% record from the previous assessment period of each independent research fellow moving on to an indefinite post.

New academic research staff each receive formal induction, a mentor to guide them through UEA processes (including probation), start-up funding and equipment according to research needs, and, in common with all staff, annual appraisal and access to staff development processes. In the School, teaching responsibilities are reduced over the first 1-2 years in post, and staff also participate in the Master of Arts in Higher Education Practice (MA-HEP), a professional development course for new academics. Following confirmation of appointment, staff are free to retain their mentor, while Theme Leaders and Directors are available for additional support.

There were four retirements from the School during the assessment period, with subsequent new appointments ensuring net growth as planned in our overall strategy. With regards to succession planning, 12 current academic research staff in the School will be at traditional retirement age by 2028. Although the exact number of retirements cannot be predicted, we will pursue our strategy of growth with follow-up appointments across all four themes. Because retirements tend to be by senior staff, and new posts are advertised at Assistant Professor level, each replacement will recalibrate the unit's demographic composition. Moreover, we are confident that the unit will continue to grow beyond replacement level in accordance with our strategy.

Support for individuals at the beginning of their research careers

Staff at the beginning of their research careers are integral to the strategy, culture and success of the unit. Accordingly, informed by our overall strategy and the Concordat to Support the Career Development of Researchers, we support them using multiple mechanisms:

Contract Research Staff:

- *Induction and mentoring:* On appointment, there is a formal induction to the School and research theme led by the PI, who then provides continuous mentorship, reinforced by annual appraisal. This way, several Contract Research Staff have been mentored into successful grant applications as Researcher Co-Investigators (e.g. Fowler, Rostant) and **Mok** was mentored into a successful application as a PI for a British Heart Foundation grant.
- *Profile within unit:* Contract Research Staff have multiple opportunities to present their work, including at the University-wide Annual Researcher Summit, in the annual School Research Colloquium and within the seminar series of the themes and virtual centres. For example, the Centre for Ecology, Evolution and Conservation holds an annual two-day conference for

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Contract Research Staff and PGR students (the highly popular 'Rebellion'), with costs subsidised by the School.

- *Career development opportunities:* In addition to guiding Contract Research Staff towards the training and professional development opportunities open to all staff (see above), the School encourages them to join PGR student supervisory teams and provides a mentoring scheme in gaining teaching experience, especially valued by those seeking careers as university academics.
- *Contract Research Staff liaison:* The School has a Contract Research Staff Coordinator, who liaises with Contract Research Staff and represents their interests. Ensuring their voice is also heard directly, a Contract Research Staff member (Eldred) chairs a Research Staff Forum and, along with any other member wishing to attend, regularly meets the Head of School.

Early Career Researchers:

- *Induction and mentoring:* The submitted staff include 13 Early Career Researchers. Early Career Researchers recruited as academic research staff receive the same support as all new academic staff, including induction, mentoring and start-up funds. Those recruited as independent research fellows, including external applicants, are also aided in preparing their fellowship applications through an assigned mentor and access to the University's Research and Innovation Services, as well as via mock interviews. This strategic support led to successful fellowship applications as detailed above. Independent researchers receive similar support, helping **Crombie**, for example, to win a junior fellowship (Leverhulme Early Career).
- *Other support:* Early Career Researchers can apply for funded projects to supervise in a dedicated Faculty of Science-led PhD studentship competition. In addition, the Director of Research runs a grant-writing workshop for all new appointments including Early Career Researchers. For **Lehtovirta-Morley**, all these various support modes helped her win an ERC Starting Grant. Similarly, **Lea-Smith** won a Human Frontier Science Programme grant as PI within two years of his appointment as Assistant Professor.

Study leave and exchanges between academia and business etc.

As per University policy, there is an annual call for study leave (for up to one semester for every six semesters worked), which is available to all academic staff, including part-time staff. The School adopts a highly flexible approach to study leave for research or impact. For example, **Brearley** took short-term leave to visit Taiwan and meet industry representatives to help consolidate his submitted Impact Case Study. **Yu** won a Leverhulme Fellowship that paid for teaching buy-out enabling him to take extended leave (18 months) to focus on research and his submitted Impact Case Study.

Consistent with our strategy for impact and aided by the Entrepreneur-in-Residence and University business relationship managers (Sections 1.3, 3.1), we deploy a variety of procedures to facilitate exchanges with business, industry and non-academic organisations:

- We encourage grant applications with business/industry and support staff seeking paid consultancies (Section 3.2); e.g. **Wormstone**'s consultancy funds a partial buy-out from other duties to allow him to focus on research and impact, including his submitted Impact Case Study.
- We host visits by business to facilitate collaborations; e.g. **Fountain** organised visits by AstraZeneca and Eli Lilly and Company to develop impact on drug development. Reciprocally, we facilitate visits by staff to industry, as in **Brearley**'s leave described above.
- We work with NGOs to advance our research and impact in conservation biology; e.g. **Gill**'s hosting of seconded RSPB scientist Dr Jennifer Smart (Section 4.2).
- Lastly, we recognise industry or NGO partners who have developed significant, extended relationships with the unit by supporting their applications for UEA Honorary Fellowship.

Rewards and recognition for staff for research and impact

In line with the overall strategy, the unit supports, enables and rewards staff achievements in research and impact by multiple, interrelated mechanisms, as detailed fully in Section 3.1.

2.2 Postgraduate research students*Overview*

Postgraduate research (PGR) students are essential to the unit's research vitality and sustainability. Simply put, they form a core part of our research activity and, through them, we train the next generation of skilled researchers. PGR students within the unit are registered in the School, and their programmes are overseen by the Faculty of Science Graduate School or the Norwich Bioscience Institutes Graduate School, both in turn coordinated by the UEA Doctoral College. Further assuring integrated approaches, unit staff (**Clark, Gage** and **Münsterberg**) sit on the management boards of each of our DTPs (EDESIA, ARIES and Norwich Research Park DTPs, respectively).

In the assessment period, the standing population of the unit's PGR students averaged 266 registered students each year (94% being PhD students), growing substantially from 244 students per year for the first four years to 294 per year over the last three. This was reflected in the intake (totalling 400 new PhD students) averaging 49 students per year for the first four years and growing to 68 per year over the last three.

Approach to recruitment

Recruitment of PGR students adheres to the UEA Code of Practice for Staff - Equality and Diversity (Section 2.3), which includes Protected Characteristics, and to UEA's Code of Practice for Research Degrees. Within this framework, the unit aims to recruit excellent students from as wide and diverse a pool of candidates as possible. First, we ensure the diverse composition of recruitment panels. Second, panel members and prospective supervisors have completed mandatory Recruitment & Selection and Diversity in the Workplace training, and all supervisors complete training in Best Practice in Research Supervision every three years. Third, recruitment is via open calls, with every applicant (funded or self-funded) undergoing a formal selection process involving senior staff outside the supervisory team as well as the PGR Service. Reflecting their diverse backgrounds, of new PGR students in the assessment period, 61% were Home students, 22.5% EU and 16.5% international.

Funding of studentships

The unit has been exceptionally successful in winning DTP PhD studentship funding, having been a key partner in four successful applications for DTPs over the assessment period – three from UKRI funders and one from a major charity. **Chapman** and **Gage** played central roles in preparing the BBSRC and NERC applications, respectively. As a result of this funding success, the unit has benefited from DTP funding for the entire assessment period:

- *Norwich Research Park DTPs (BBSRC):*

The unit was a key partner in two successful applications to the BBSRC's DTP competitions, each funding the



norwich research park

Doctoral Training Partnership

Norwich Research Park DTP led by the John Innes Centre. In DTP2 (2014), this was awarded 34 studentships per year (including nine iCASE studentships) plus an additional nine studentships from the National Productivity Investment Fund. In DTP3 (2019), it was awarded 24 studentships per year (including six iCASE studentships), with an additional eight studentships per year being funded by the Norwich Research Park DTP's Partners and Associate Partners. As the DTP was also funded to 2014-15 by BBSRC's DTP1, as at the end of 2019-20 the unit has received an unbroken eight intake years of BBSRC-funded PhD students, with a further five years to come. In total, 242 PhD students were recruited to the DTP in the assessment period (to 2018-19).

- *ARIES DTP (NERC)*: In NERC's DTP1, the EnvEast DTP, led by UEA, benefited from the 2013 award of 12 studentships per year from 2014-15 to 2018-19. In 2018, the unit was a key partner in a successful new application to NERC's DTP2 that funded EnvEast's successor, the ARIES DTP, again led by UEA. This was awarded up to 12 studentships per year from 2019-20 to 2023-24. Overall, 60 students were recruited to the EnvEast DTP in the assessment period (to 2018-19).
- *EDESIA DTP (Wellcome Trust)*: In 2019, the unit was a key partner of the EDESIA DTP, co-led by the John Innes Centre and UEA, which won Wellcome Trust DTP funding to provide five studentships per year from 2020-21 to 2023-24 to advance the study of plant-based nutrition and health. **Clark** is a current EDESIA Director. Total funding from the Wellcome Trust to the DTP will be £5.3M.



The unit has also been successful in winning PhD funding from other external sources, including charities (e.g. Dunhill Medical Trust), industry (e.g. AB Vista), overseas partner universities (Southern University of Science and Technology, Shenzhen, China) and overseas governments (e.g. Saudi Government). It also attracts large numbers of self-funded PGR students (92 in the assessment period). Finally, it received PhD studentships from investment by the Faculty of Science, both through top-up funding to the DTPs (2-3 studentships per year for both the Norwich Research Park DTP and EnvEast/ARIES DTPs), and Faculty studentships targeted at Early Career Researchers and staff in areas outside the DTPs' remits (27 studentships over the assessment period). Overall, of all new PGR students in the assessment period, 21% were UKRI-funded, 31% UEA- or Norwich Research Park-funded, 24% funded by other sources including the NHS, charities and industry, 20% self-funded and 4% funded by overseas governments. In sum, in an increasingly competitive environment, the unit has achieved excellent PGR funding success across multiple sources, thereby maintaining vitality in its PGR activity and its sustainability into the future.

Monitoring and support for PGR students

All PGR students follow a formal monitoring and progression process mandated by the UEA Doctoral College. Formal progress meetings occur every four months and, for PhD students, include the probationary meeting, which is held within the first 12 months under an independent chair. To support them, students have access not only to their supervisory team, but also to the Director of PGR (**Kelemen**), the Senior Adviser and Disability Officer and UEA's Student Support Services (including a dedicated well-being team in the Faculty of Science). More generally, students have representation on the Faculty of Science Postgraduate Research Committee, which, chaired by the Associate Dean of PGR, enables them to shape PGR policy. In addition, the unit and DTPs strive to develop each year's PGR student intake as a cohesive group through cohort-level events and activities, so providing a ready-made peer support group. Lastly, PGR students present their work at the annual School PGR Colloquium and their successes are celebrated as for staff (Section 3.1), underlining their integration into the unit's research culture.

Evidencing the effectiveness of these processes, in the assessment period the unit's PhD students achieved high rates of completion of their theses (School average, 92%), with 41 doctoral degrees per year being awarded across the unit. Moreover, satisfaction rates are high and growing, with the biennial Postgraduate Research Experience Survey demonstrating, from PRES 2015 to PRES 2019, satisfaction rates increasing from 87% to 92%, 73% to 76% and 88% to 91% for Professional Development, Research Culture and Research Skills, respectively, among the School's PhD students, with all these values exceeding sector averages.

Skills and career development for PGR students

The UEA Code of Practice for Research Degrees commits the unit to providing transferable skills and employability training to all PGR students, taking into account national standards including Roberts 'SET for Success' report. Hence, all PGR students follow a Training Pathway from their DTP or from the Faculty of Science. These Pathways are linked to the Vitae Researcher

Development Framework and involve a minimum of 10 days full-time training per year or equivalent. The Pathway specifies mandatory training requirements and offers proposals for broader professional and personal development. The proposals are then individually tailored via a Training Needs Analysis completed by each student at the PhD's start and updated annually as a Personal and Professional Development Plan. Students receive personalised feedback from the supervisory team, a dedicated PGR Training Coordinator and (typically) a DTP board member. Training is delivered by a variety of qualified staff, including the Training Coordinators and external providers. It is evidence-based, responsive to student feedback and includes training for impact and employability. For example, PGR students may take up 3-month external placements (mandatory under the Norwich Research Park DTP). Students also have access to dedicated advisers in the Careers Service and are supported in participating in the annual i-Teams programme focused on innovation. Across all programmes, a substantial number of PhD students are co-supervised with external industry/NGO partners under the CASE/iCASE model (Section 3.2). Lastly, the DTPs and Faculty of Science each provide funds for PhD students to attend external conferences, so enhancing employability prospects for those students selecting an academic career.

2.3 Equality and diversity

Overview

The unit is governed by the UEA Code of Practice for Staff - Equality and Diversity (REF5a). This covers all aspects of equality and diversity, including staff and PGR student recruitment and support. It addresses the nine Protected Characteristics, each of which is covered by its own specific Code of Practice. In line with these frameworks, all staff undergo mandatory Diversity in the Workplace training every two years, and undertake to foster a respectful, supportive and inclusive environment for all.

Beyond these requirements, the unit strives to achieve best practice in equality and diversity in every aspect of its activity (e.g. Sections 1.2, 3.5, 4.1). Reflecting this, the School is proud to have held Athena SWAN accreditation throughout the assessment period (Bronze award from 2013, Silver award from 2017). Since gaining Silver in 2017, we have been implementing an Athena SWAN Action Plan committing us to renewing our Silver status in 2021 and then working towards Gold status. The Action Plan, along with all equality and diversity implementation, is overseen by the School's Equality and Diversity Committee. Composed of representatives at all levels, including the School's Director of Research, and co-chaired by **Immler** and **Wormstone**, this committee meets monthly and reports to the School Executive. It routinely surveys staff and students for their views to enable continual improvement in our equality and diversity culture.



Specific equality and diversity measures within the unit

The unit implements a number of specific measures, both formal and informal, to achieve a professional, supportive and inclusive research environment for all:

- **Protected Characteristics:** The unit recognises its obligation to those with Protected Characteristics in staff and PGR student recruitment and support (Section 2.1, 2.2). All staff have access to ResNet, a UEA-supported network promoting equality and fairness throughout the Norwich Research Park. The School has a Senior Adviser and Disability Officer and individuals with disabilities are represented on the Equality and Diversity Committee. PGR students with disabilities receive support to facilitate their research via a system of recorded 'reasonable adjustments' and/or via needs arising, including support through the provision of paid assistance. Staff also have access to UEA's BAME Staff Network and in 2019 the School started its own 'BAME in BIO' initiative to support BAME members including PGR students. In the assessment period, 29% of the 24 new staff

Unit-level environment template (REF5b)

recruited to the unit were female, as against 20% of existing staff being female, evidencing progress towards greater gender balance.

- *Wellbeing:* We aim to ensure staff wellbeing through our support mechanisms for all staff and PGR students (Sections 2.1, 2.2). Less formally, we observe events such as Time to Talk Day and World Mental Health Day, and solicit suggestions for wellbeing actions from staff and students.
- *Access to resources, promotion and senior roles:* The unit operates procedures designed to maximise equality and diversity in promotion (Section 2.1) and access to resources (Section 3.5). Appointment to senior School roles is via open calls and this has helped broaden take-up, such that the 15-strong School Executive currently has a representative gender balance (6F, 9M). Female staff can obtain financial support to attend Aurora, a leadership development programme run by Advance HE.
- *Flexible working:* The unit adheres to UEA Flexible Working Guidelines (REF5a) and accordingly aims for all staff enjoying a healthy work-life balance. Staff can request flexible working arrangements and this is well supported. For example, a staff member whose family life is based overseas alternates weeks working from home and at UEA. To allow parents or carers easily to sit on and attend School committees or similar meetings, these are preferentially held within core working hours (10:00-16:00).
- *Part-time staff:* Academic research and Contract Research Staff on part-time contracts receive the same support as full-time staff to pursue their career pathways. For example, they follow exactly the same annual appraisal and promotion processes.
- *Career absences:* The Faculty of Science's Return to Work/Family Support Fund is available to all staff and PGR students to assist the transition back to work and career development following absence, e.g. after parental leave or leave for adoption, caring or ill health. Twelve research staff in the School took parental leave/career breaks in the assessment period and two requested and received Fund support. The Fund also provides costs of caring for dependants to facilitate staff attending conferences, networking events or professional development events.

Equality and diversity in the construction of the unit's REF submission

The unit's REF2021 submission has been constructed in compliance with equality and diversity requirements as set out in UEA's REF2021 Code of Practice. This includes fair procedures for identifying staff with significant responsibility for research, determination of independent researcher status and selection of outputs. REF decision-makers for the unit all received Unconscious Bias training. Within the unit, outputs for potential submission were solicited via open calls and/or discussion with staff. Outputs underwent a series of assessments of quality involving internal and/or external assessors. Internal assessment was carried out collectively by submitting staff, and all assessors received instruction on assessing output quality according to REF criteria. Anonymised assessment scores were fed back to authors, giving them the opportunity to reflect on and discuss them. Similarly, the submitted Impact Case Studies were selected via iterative assessments by multiple individuals within and outside the unit in Annual Impact Review meetings overseen by the Pro-Vice Chancellor for Research & Innovation, with feedback provided at each stage. Reflecting these approaches, our final set of submitted outputs is broadly representative of the staff profile (21% led by female staff versus 23% female staff, 16% led by Early Career Researchers versus 17% Early Career Researchers).

3. Income, infrastructure and facilities

3.1 Mechanisms for promoting, facilitating and funding research and impact

Encouraging, enabling and funding research and impact activity is key to our overall strategy and is realised by maintaining a culture of submitting applications and supporting this via multiple mechanisms:

Unit-level environment template (REF5b)

- Directors of Research and Innovation who sit on the School Executive and the Faculty of Science's Research and Innovation Executives, with briefs to provide strategic direction for, and champion, research and impact.
- Theme Leaders for each research theme, charged with coordinating strategy for, and ensuring vitality of, their themes.
- A Research Committee, chaired by the Director of Research and including Head of School, Director of Innovation, Director of PGR and Theme Leaders, to coordinate research and impact activities, promote collaboration and ensure effective use of infrastructure.
- Strong support for staff to pursue research and impact funding, aided by the University's Research and Innovation Services, whose dedicated biological sciences team supports grant applications/management, while an impact team supports business relationships; and, in The Sainsbury Laboratory, by the 2Blades Foundation, a charity specifically established to achieve impact.
- A tailored set of UEA internal impact funding schemes to which staff are encouraged to apply via regular calls (Proof of Concept, Innovation Development, Strategic, Impact Acceleration, HEIF Impact, Associate Dean, GCRF and Industrial Strategy Funds).
- Additional impact funding schemes available, including the Norwich Research Park Translational Fund and the regional EIRA (Enabling Innovation: Research to Application) fund supporting innovation in the East of England.
- Two Faculty-level committees each chaired by a unit member (**Balk, Gill**) to provide internal review and supportive feedback for draft grant applications and fulfil UKRI demand management requirements, i.e. the NERC (Life Sciences) and BBSRC & MRC (Non-clinical) Committees.
- Organisation of, and/or participation in, funders' visits, e.g. British Heart Foundation visit (2019) organised by **Fountain** and two Faculty of Science-led NERC theme days (2016, 2019), including roundtable discussions to allow us to align with funders' priorities and expectations; and industry visits (Sections 2.1, 4.2).
- Annual University-wide Research Activity Planning for all staff, focused on outputs, impact, external income and PGR student supervision (Section 2.1); in addition, each internally registered Impact Case Study is reviewed annually at Faculty and Pro-Vice Chancellor level.
- Communication of research and impact news and calls via monthly newsletters from the Directors of Research and Innovation, along with a weekly Faculty of Science funding opportunities bulletin.
- Recognition and rewards for research and impact success through: workload adjustments; buy-out of teaching responsibilities; leave periods; promotion or, for sustained research and/or impact excellence at a level beyond an applicant's current grade, salary increases via special increments or discretionary awards; and prizes in the annual UEA Innovation and Impact Awards contest.
- Uniquely within UEA, the School appointed a Royal Society-funded Entrepreneur-in-Residence (Dr David Dent; appointed 2019, renewable in 2021). As Chair of the BBSRC Follow-on-Fund panel with extensive commercial experience, he holds a brief to provide us with expert help in sustaining our current impact activities and identifying new impact opportunities.
- Vigorous seminar programmes, including the School's flagship Open Lecture series for external speakers, along with seminar series of the research themes and virtual research centres and two annual all-day colloquia, one focused on academic and Contract Research Staff (BIO Research Colloquium) and one focused on PGR students (BIO PGR Colloquium).
- Enthusiastic celebration of research and impact achievements via the monthly newsletters, social media and Head of School's weekly 'good news' message.

3.2 Research and impact income

Research income in the assessment period

Evidencing the success of our strategy and implementation mechanisms, the unit's HESA-reportable research income was £65.6M, of which £35.7M came from Research Councils (or The Royal Society and British Academy). There were 633 active, funded projects with a total UEA

value of £75.4M, including £46M from UKRI, £16.8M from UK Charity and £7.7M from the EU. PI-led awards included over 80 grants with UEA values of £0.25M-£1.5M each. The unit also received research income-in-kind of £635K. Five ERC grants started in the assessment period, i.e. two Advanced (**Jones, Kamoun**), two Consolidator (**Maklakov, Zipfel**) and one Starting (**Lehtovirta-Morley**), and there were two additional successful applications for Consolidator Grants (**Immler, Suh**), leading to a total ERC grant award value of >£10.3M. Other major funders were BBSRC, NERC, MRC, EU Horizon 2020 (ERC plus other schemes), Royal Society and Leverhulme Trust, plus medical charities (e.g. British Heart Foundation, The Dunhill Medical Trust and Versus Arthritis). Further evidencing the success of our strategy, we achieved excellent success rates for applications to major UKRI funders in the assessment period, with UEA success rates standing at 30% (BBSRC) and 37% (NERC), each well above national averages (25% and 30%, respectively).

To win larger, multi-partner grants (consortia), we apply the same mechanisms within the strategy, aided by our approach to interdisciplinary work (Section 1.4) and administrative support from the International Research Project Manager and European Funding Manager within the University's Research and Innovation Services. As a result, we lead and participate in a number of competitively-funded consortia (sums are total awards):

- Dunhill Medical Trust-funded consortium including **Clark** and **Dalmay** led by external colleagues at the University of Newcastle (£1.0M).
- EU Horizon 2020-funded consortia including **Dalmay** (EUR 3.2M), **Dicks** (EUR 3.0M), **Monk** (EUR 4.1M), **Pöschl** (EUR 7.8M) and **Wheeler** (EUR 4.2M) respectively, each with multiple external colleagues.
- GCRF-funded consortia with external colleagues: on watershed protection in Mexico led by **Bell** (£0.3M); on protecting biodiversity in Colombia led by **Di Palma** (£6.5M); and on crop protection in sub-Saharan Africa and Bangladesh, respectively, led by **Talbot** (£1.7M) and by **Talbot** and **Kamoun** (£0.75M).

The ultimate payoff of achieving funding is in outputs, impact and training of research staff, and so links between our funding and high-quality outputs are integral to our research efforts. Such links are too many to detail, but, for example, of outputs showcased above (Box 1.1), **Clarke's** on a protein complex acting as a transmembrane molecular wire in bacteria was funded by grants from BBSRC, **Todd's** on dimethylsulfoniopropionate by grants from NERC, **Gage's** on sexual selection by grants from NERC and the Leverhulme Trust and **Jones's** work on plant immunity by multiple grants including an ERC Advanced Investigators grant.

Impact income in the assessment period

Our strategy has also found success in terms of impact income. This included £1.45M from paid consultancies held by 11 staff, £0.21M from industrial or NGO partner contributions to 25 CASE/iCASE PhD studentships, £562K in 43 awards from competitively-selected UEA internal impact funds and £187K from the Norwich Research Park Translational Fund and the Enabling Innovation: Research to Application fund (Section 3.1). In addition, The Sainsbury Laboratory received £7.44M from research contracts with commercial companies and £3.49M from patent royalties. Multiple staff members have won UKRI Industrial Partnership Awards, LINK Grants, Pathfinder Grants or Innovation Grants supporting impact elements of research (e.g. **Brearley, Hemmings, Hutchings, Wheeler** and **Yu**). Overall, both nationally and internationally, unit members have held funding with 112 external businesses or institutions as Collaborators and 60 as Project Partners.

Impact income has been used to help produce both our submitted and maturing Impact Case Studies. For example, **Brearley, Dicks, Wormstone** and **Yu** variously received income from several of UEA's internal impact funds, as well as from the Enabling Innovation: Research to Application fund, helping them develop their submitted cases on, respectively, improving animal feeds, global policy for pollinators, better intraocular lens for cataract surgery and the spin-out

Unit-level environment template (REF5b)

company NatureMetrics. Outside the submitted cases, staff in all our impact sectors (Section 1.3) enhanced their impact work using awards from the internal schemes available. In addition, staff pursuing impact have benefited from iCASE partner support for PhD projects, including benefits-in-kind from partners' time and expertise, for example from AB Vista (**Brearley, Hemmings**), AstraZeneca (**Fountain**), HL Hutchinson Ltd (**Dicks**) and Merck (**Fountain**).

3.3 Infrastructure supporting research and impact

The infrastructure supporting research and impact comprises a range of facilities from benchtop equipment in individual laboratories funded by external project grants and the Pro-Vice Chancellor for Research & Innovation's Capital Equipment Fund, to large-scale Instrument Platforms funded by UEA, Norwich Research Park institutes and/or external capital equipment awards.

The Faculty of Science Instrument Platforms (Bio-imaging, Elemental Analysis, Mass Spectrometry, Nuclear Magnetic Resonance, Stable Isotope Analysis, Structural Imaging and X-Ray Imaging) provide centrally supported facilities for all unit members. Each has an academic lead for strategic oversight, with **Mogensen** leading Bio-imaging and **Wormstone** leading Structural Imaging. In addition, **Menke** leads a proteomics facility (TSL Proteomics) in The Sainsbury Laboratory. Keeping the unit's research at the technical cutting edge is central to our overall research and impact strategy. Consistent with this, substantial investment has been made in the Faculty of Science Platforms in the assessment period. For example, unit members contributed to two successful cross-Norwich Research Park bids to the BBSRC 17ALERT and 19ALERT calls, winning £0.84M in total from BBSRC topped up by £0.24M from UEA to fund new instruments for the Mass Spectrometry Platform. These awards provide an excellent example of the Norwich Research Park's critical mass being leveraged into capital equipment funding success. In addition, successful bids led by **Mogensen** and **Wormstone** in the 2019 and 2020 competitions for UKRI Capital Equipment awards to UEA resulted in the Bio-imaging and Structural Imaging Platforms receiving totals of £0.58M and £0.70M for upgraded confocal and scanning electron microscopes, respectively.

The School also houses a set of specific facilities serving its research themes:

- Controlled Environment Facility (a suite of climate-controlled rooms for culturing invertebrates, amphibians and fish) (*Cells & Tissues; Organisms & Environment*).
- Disease Modelling Unit (animal facility co-hosted by the Faculty of Medicine and Health in the Biomedical Research Centre) (*Cells & Tissues*).
- Wolfson Fermentation Suite (for microbial culture) (*Molecular Microbiology*).

These facilities receive core technical support and are maintained by responsive mode grants, UKRI Capital Equipment awards and recurrent investment from UEA and the unit. For example, the Controlled Environment Facility received £70K for new humidifiers from the 2020 UKRI Capital Equipment award and the Disease Modelling Unit/Biomedical Research Centre received a £2.51M upgrade from UEA. UEA invested an additional £1.64M in maintaining fume cupboards and refrigeration facilities in the Faculty. Lastly, the School received £0.27M through successful bids to the Pro-Vice Chancellor's Capital Equipment Fund, and invested in infrastructure for new staff, including an aquarium for **Immler** and refitted laboratories for **Lehtovirta-Morley** and **Maklakov**.

Unit members have access to other high-quality equipment across the Norwich Research Park, including the Park's Biorepository of tissue samples for biomedical research. The Park's Earlham Institute, a BBSRC-funded national centre for genomic research and sequencing, provides unparalleled access to cutting-edge sequencing platforms and expertise, including single-cell sequencing.

Unit-level environment template (REF5b)

Technical support is provided by the Faculty of Science, with dedicated technicians for each research theme, a Platform Manager and specialist technical support for each Instrument Platform and a Laboratory Manager for Research and Related Activities for overall coordination. The Faculty of Science also provides core services such as autoclaving and glass-washing. Research computing, including access to the High-Performance Computing cluster, essential for the unit's bioinformatics research, is centrally supported by the University, having received £520K per year in investment since 2014. Scholarly research infrastructure is provided by the UEA Library, in which a biological sciences Academic Librarian ensures access to informational resources and support for reference management and search tools.

Overall, these facilities underpin the research programmes of multiple groups and have led to a suite of key outputs. For example, the Bio-imaging Platform was central to the work of **Münsterberg** in discovering a role for bone morphogenetic proteins in heart formation (2014. *PNAS*; DOI: 10.1073/pnas.1321764111). The Controlled Environment Facility enabled **Gage's** pioneering research on the effect of higher temperatures associated with climate change on insect reproduction (2018. *Nature Communications*; DOI: 10.1038/s41467-018-07273-z; 2019. *eLife*; DOI: 10.7554/eLife.49452). Multiple studies in the unit have used the sequencing capability of the Earlham Institute and proteomics facility of TSL Proteomics. Similarly, the unit's facilities have been key to generating impact, with, for example, **Wormstone's** submitted Impact Case Study drawing directly on the Bio-imaging Platform.

[3.4 Collaborative use of research infrastructure](#)

Unit members are both providers and users of facilities shared across HEIs. For example, the Controlled Environment Facility has been used to host the work of visiting researchers from the Universities of Ottawa and Warsaw. **Richardson** collaboratively shares a field station in the Seychelles part-funded by UEA with colleagues from the University of Sheffield and University of Groningen, The Netherlands, for their long-term ecological and genetic field study of the Seychelles Warbler (e.g. 2017. *PNAS*; DOI: 10.1073/pnas.1704350114; 2019. *Nature Communications*; DOI: 10.1038/s41467-019-09229-3). **Clarke** used the external Diamond Light Source national synchrotron facility at Harwell for his work on a protein complex acting as a transmembrane molecular wire in bacteria (2020. *Cell*; DOI: 10.1016/j.cell.2020.03.032). Through the unit's extensive portfolio of iCASE PhD studentships (Section 3.2), we also benefit from access to the equipment and facilities of our industrial and other non-academic partners.

[3.5 Equality and diversity in accessing research and impact funding and infrastructure](#)

Access to all funding and infrastructure is delivered mindful of our equality and diversity commitments in fairly allocating resources (Section 2.3). All staff receive support for achieving research and impact (Section 3.1) and have equal access to the Instrument Platforms, with allocation decisions for these and for funds from the UKRI Capital Equipment awards being made by formal Faculty of Science or University-led committees based on need and merit. We also provide mentorship and targeted support for Early Career Researchers (Section 2.1). Evidencing the success of this approach, for example, the percentage of grants held (by value) by female PIs in the unit was 28%, fully in line with the unit's percentage of female staff (23%).

[4. Collaboration and contribution to the research base, economy and society](#)

[4.1 Research collaboration](#)

Collaboration is integral to the unit's overall strategy, allowing it to address scientific issues not easily tackled by smaller teams. Collaborative teams – internal and external – are facilitated by all of our mechanisms for encouraging research and impact (Section 3.1) and interdisciplinarity (Section 1.4), as underpinned by our ethos of mutual help and collegiality and commitment to equality and diversity. Logistically, they are supported by the University's Research and Innovation Services and International Office. In addition, UEA is part of the Aurora Network of

Unit-level environment template (REF5b)

universities, a group of nine European research-intensive universities dedicated to fostering common approaches and collaboration, and co-hosts PhD studentships through a partnership with the Southern University of Science and Technology (SUSTech), Shenzhen, China. The effectiveness of our approach is evidenced by 82% of the unit's outputs as a whole having external coauthors, with 67% of the total having international coauthors, who come from over 100 countries.

Examples of our collaborations include:

- Within the Norwich Research Park, collaborations by **Hemmings** and **Hutchings** with John Innes Centre researchers on, respectively, identifying plant natural products (2016. *PNAS*; DOI: 10.1073/pnas.1605509113) and antibiotic discovery (e.g. 2019. *Nature Communications*; DOI: 10.1038/s41467-019-11538-60).
- Nationally, **Bell**'s collaboration with a team led by the University of Cambridge on myxoma virus in rabbits (2019. *Science*; DOI: 10.1126/science.aau7285).
- Internationally, **Robinson**'s collaboration with scientists in China, UK and USA discovering a previously unrecognised mechanism of cancer growth control (2020. *Cell*; DOI: 10.1016/j.cell.2020.02.003).

In addition, large-scale consortia producing sequenced genomes illustrate par excellence the value of international collaboration, with unit staff having led or co-led genome projects for ferret, rabbit and spotted gar (**Di Palma**) and tsetse fly (**N Hall**), and contributed to such projects for Asian seabass, bumble bee, elephant, koala and tuatara (**Bourke, Dalmay, Di Palma, Haerty, Suh**). Similarly, staff led very large-scale comparative genomic studies for wheat (**A Hall**: 2020. *Nature*; DOI: 10.1038/s41586-020-2961-x) and contributed to such projects for birds (**Suh**: 2020. *Nature*; DOI: 10.1038/s41586-020-2873-9) and mammals (**Haerty**: 2020. *Nature*; DOI: 10.1038/s41586-020-2876-6).

Lastly, unit staff have produced high value community resources, exemplifying both collaboration and contribution to the sustainability of the discipline. For example, **Jones** led a study inventorying disease resistance genes in *Arabidopsis* (2019. *Cell*; DOI: 10.1016/j.cell.2019.07.038) and **Macaulay** published a protocol for parallel genome and transcriptomic sequencing of single cells (2016. *Nature Protocols*; DOI: 10.1038/nprot.2016.138).

[4.2 Impact: relationships and contributions](#)

Both our set of six submitted Impact Case Studies and our wider portfolio exemplify the unit's contribution to the economy and society. To realise this, staff have engaged with users aided by our impact support mechanisms (Section 3.1). For example, outside the submitted cases, **Butler** has engaged with the EU Commission to design an algorithm for conservation and development planning; **Lehtovirta-Morley** has engaged with Defra and Norwich City Council over remediation of waste sites; and **Talbot** is engaging via a GCRF-funded project with potential users of disease-resistant rice in sub-Saharan Africa. In addition, **Gill** hosts Category C staff member Dr Jennifer Smart, a senior RSPB scientist working full-time in the School as a seconded employee and contributing substantially to the research environment via joint grants (NERC and Defra), CASE studentships and outputs.

Building on the submitted cases of Baulcombe and **Wormstone**, a further cluster of developing Impact Case Studies exemplifies the unit's biomedical collaboration and impact. For example, **Chantry** has engaged with AstraZeneca over drug development for cancer treatment; **Clark** is part of an external team funded by Versus Arthritis conducting clinical trials of nutritional interventions in arthritis; **Fountain** has engaged with Afferent Pharmaceuticals, AstraZeneca and Merck over drug development based on purinergic signalling and shares British Heart Foundation grants with Turner from the Norfolk and Norwich University Hospital; and **Gavrilovic**

is collaborating with John Innes Centre and Norfolk and Norwich University Hospital colleagues to develop in vitro human skin models.

All these collaborations, as well as delivering impact, have substantially enriched the unit's research environment, by supporting staff research programmes in their widest sense and employing Contract Research Staff to the benefit of both research teams and potential end-users.

[4.3 Engagement with diverse communities](#)

The School runs a full and varied programme of public engagement and outreach, coordinated by a Director of Engagement (Academic, Teaching & Scholarship staff colleague Blake) and supported by a Communications Officer (**Spurgin**), social media presence (the School's Twitter handle is @biouea) and UEA's Press Office. In addition, in 2019 UEA appointed biologist and award-winning broadcaster Ben Garrod as Professor of Evolutionary Biology and Science Engagement to conduct teaching and outreach in biological sciences. We therefore communicate our research and impact achievements to a very wide audience, including school children, local societies and the public nationally and internationally. Accordingly, engagement activity is valued in promotion decisions, and celebrated at University level. For example, several staff have been honoured as Vice Chancellor's UEA Media Stars, including **Bell** in all four years of the award, and **Hutchings** won the UEA engagement award for 'Outstanding Contributions to Public and Community Engagement', 2015. Unit members have also been externally recognised for engagement, with **Dicks** receiving Defra's Bees' Needs Champion Award in 2018 and **Hutchings** receiving the Microbiology Society's Microbiology Outreach Prize 2019.

Highlights of our hundreds of individual engagement events include:

- Exhibits on bacteria (**Clarke**) and biodiversity (**Gage, Spurgin and Taylor**), Latitude Festival, Suffolk, 2018 and 2019.
- **Di Palma**'s participation in a panel discussion of biodiversity, Cheltenham Science Festival, 2020.
- **Dicks**'s exhibits on pollinators, Bees' Needs Week, London, 2018 and 2019.
- **Hutchings**'s exhibits on antibiotic discovery at the Royal Society Summer Science Exhibition 2014, BBSRC Great British Bioscience Festival 2014 and Big Bang Science Fair 2015; plus an 18-month sponsored exhibit on 'Superbugs' at the Science Museum (2017-2019).
- **Hutchings**'s and **Immler**'s presentations of 'Science Lates', Natural History Museum and Science Museum, London, 2018 and 2019.
- Unit staff participation (posters, exhibits) in two annual public science events in Norwich, i.e. 'Super Science Saturday' and the Norwich Science Festival.

Through events like these we have reached very wide audiences, with, for example, an estimated 1M people visiting **Hutchings**'s Science Museum exhibit. We also regularly publicise our work through press releases (approximately one per month) and interviews on broadcast media. Through such means, in the assessment period the School averaged over 850 media mentions per year both nationally and internationally.

[4.4 Interdisciplinarity and responsiveness to national and international priorities](#)

Applying the unit's mechanisms for supporting interdisciplinary research (Section 1.4), we have achieved some notable outcomes:

- Evolutionary geneticist **Spurgin** collaborated with epidemiologists and mathematicians to use citizen-science data to model COVID-19 control strategies, which later led to a well-cited publication (2020. *Nature Medicine*; DOI: 10.1038/s41591-020-1036-8).
- **Di Palma** is leading a £6.5M GCRF-funded interdisciplinary programme (GROW Colombia) to strengthen Colombian research capability in the biological sciences, computational biology and socio-economics, with the goal of protecting Colombia's rich biodiversity.

- **Bell** co-led a GCRF-funded project with Few, School of International Development, to take an interdisciplinary approach to watershed protection in Mexico.
- Following the 'speed-dating' event with the Quadram Institute, cell biologist **Gavrilovic** collaborated with microbiologist Webber (Quadram Institute) to win BBSRC funding to use in vitro human skin models to investigate antiseptic tolerance in premature babies.
- Lastly, a major coup for our approach of capitalising on the synergies present across the Norwich Research Park was the successful interdisciplinary application to the Wellcome Trust for the EDESIA DTP centred on plant-based nutrition and health (Section 2.2), which rested on the combined expertise of biomedical researchers in the unit, health researchers in the Faculty of Medicine and Health Sciences and plant scientists in the John Innes Centre.

For both interdisciplinary and other major grant applications, we have consistently responded to national and international priorities and initiatives. For example, we responded to calls from the UK Aquaculture Initiative (**Gage**), Research England's E3 (Expanding Excellence in England) Fund (team led by **Maklakov**) and the Transforming the UK Food Systems Strategic Priorities Fund (**Dicks**). Internationally, we responded to EU Horizon and GCRF consortium calls, with funding success for multiple unit members as detailed above (Section 3.2).

We are proud that our expertise and flexibility also permitted our response to the national and global emergency represented by the COVID-19 pandemic. On site, molecular biologists from the unit joined others across the Norwich Research Park to pilot and establish a community testing facility on the Park. **Spurgin** and external collaborators won funding from the Royal Society's Rapid Assistance in Modelling the Pandemic (RAMP) Initiative, which led later to **Spurgin's** publication described above (2020. *Nature Medicine*; DOI: 10.1038/s41591-020-1036-8). **Spurgin** then became a member of the Scientific Pandemic Influenza Group on Modelling (SPI-M) of the Government's Scientific Advisory Group for Emergencies (SAGE), as well as accepting a year-long secondment on Norfolk County Council's COVID-19 Outbreak Response Team. **Bell** provided expert commentary on the pandemic (e.g. Bell D. Coronavirus: we still haven't learned the lessons from Sars. *The Conversation*, 20 January 2020). Lastly, **Macaulay** coauthored a study on the mechanisms for the loss of the sense of smell (anosmia) in COVID-19 patients (2020. *Science Advances*; DOI: 10.1126/sciadv.abc5801).

4.5 Professional contributions to the discipline, esteem and recognition

The unit's staff contribute extensively to the sustainability of the discipline. For example, several have taken roles on influential planning and strategy committees for major funders:

- **Di Palma** served on the assessment panel for the Research England International Investment Initiative (I3 Fund).
- **Gill** served on the NERC Biodiversity & Ecosystem Service Sustainability Advisory Panel, overseeing a six-year research programme with a £13M budget.
- **N Hall** served on the BBSRC Exploiting New Ways of Working Strategy Panel and the BBSRC Transformative Technologies Strategy Advisory Panel.

Staff sit on multiple grant committees and/or serve as peer review college members for major funders, including BBSRC, ERC, Leverhulme Trust, NERC and UKRI (Future Leaders Fellowships), with **N Hall** being Chair of the Wellcome Trust Biomedical Resource Committee. **Chapman** is Editor-in-Chief of *Evolution*, the leading journal in its discipline, while staff are members of editorial boards of numerous journals, including *Ecology Letters*, *EMBO Reports*, *Genome Biology*, *Journal of Animal Ecology*, *PLoS Biology*, *PLoS Pathogens* and *Proceedings of the Royal Society B*. Staff routinely serve as peer reviewers of grants and submitted papers, including for *Nature*, *Science* and highly-regarded subject journals.

Staff take leading roles in scientific NGOs and societies. For example, **Gage** is Treasurer of the Association for the Study of Animal Behaviour, **Gill** is Chair of the Board of the British Trust for

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Ornithology and **Kamoun** was elected President of the International Society of Molecular Plant-Microbe Interactions. They have also served as organisers of conferences and symposia. **Taylor** co-convened the 2018 Symposium of the Fisheries Society of the British Isles held at UEA over five days and attended by more than 180 scientists from 20 countries. Overseas, **Bell** organised the GCRF-funded Best Practice-Sharing Meeting for Watershed Dependent Cities, British Embassy, Mexico City, 2019; **Hajhosseini** was Vice-Chair of the Gordon Research Conference on Fibroblast Growth Factors in Development and Disease, USA (2018); **Maklakov** organised a Symposium at the European Society of Evolutionary Biology Congress, The Netherlands, 2017; and **Mogensen** organised the European Cytoskeletal Forum, Slovenia, 2015.

Reciprocally, many staff are invited to conferences as plenary/keynote speakers; e.g. **Gill** at the 27th International Ornithological Congress, Canada (2018); **Kingsley** at two Gordon Research Conferences (Salmonella Biology and Pathogenesis; Signaling at the Microbe-Host Interface), USA (both 2019, USA); and **Malone** and **Todd** at the annual American Society of Microbiology 'Microbe' Conference, USA (2018 and 2019, respectively); and many more have been invited presenters at conferences.

Unit staff have also influenced their research fields through publishing highly-cited reviews; e.g. **Jones** on immune surveillance across plant and animals (2016. *Science*; DOI: 10.1126/science.aaf6395) and **Zipfel** on plant signalling (2016. *Nature Reviews Immunology*; DOI: 10.1038/nri.2016.77; 2017. *Nature*; DOI: 10.1038/nature22009). In addition, since 2014, **Dicks** has coauthored influential annual horizon scans for emerging global biological conservation issues in *Trends in Ecology and Evolution* (e.g. 2020. DOI: 10.1016/j.tree.2019.10.010).

Reflecting their calibre, unit staff received high honours during the assessment period:

- **Gill** was awarded the British Ornithologists' Union's Union Medal, 2017.
- **Kamoun** was elected a member of the European Molecular Biology Organization (EMBO), 2015, and awarded the Kuwait Prize, 2016, and Linnean Medal, 2018.
- **Jones** was elected Foreign Associate of the US National Academy of Sciences, 2015.
- **Wormstone** was awarded the US National Foundation for Eye Research's Cataract Research Award for Outstanding Research Achievements, 2015.
- **Zipfel** was elected a member of EMBO, 2018.
- 3-5 staff have been among the top 1% most highly-cited researchers worldwide each year in the four years to 2020 (**Jones, Kamoun, Talbot, Win, Zipfel**).

Lastly, joining **Jones** (FRS 2003), two unit staff (**Kamoun** in 2018 and **Talbot** in 2014) received the exceptional accolade of election as Fellows of the Royal Society.