

Institution: University of the West of England, Bristol

Unit of assessment: 6 Agriculture, Veterinary and Food Science

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

### 1.1 Unit context and structure

This submission is based on the research of a collaborative group of 15 (14.2 FTE) active researchers who are members of the Centre for Research in Biosciences (CRIB; **Arnold**, Deputy Director until June 2020). Our research is organised into three strategically important themes; Plant health and disease, Agri-environmental challenges and Food science and technology.

Research in the unit is interdisciplinary and has strong links with staff returned in other units of assessment such as Allied Health Professions (UoA 3). The unit collaborates not only across the disciplines within the Faculty but also across the University including the University's Science Communication Unit, Institute of Biosensing Technology (IBST) and Enterprise Zone which support collaborations with industry and other research stakeholders. The unit delivers research and impact in areas including policy, practice, and public engagement. Names of academics whose outputs are submitted in this unit are highlighted in **bold**.

### 1.2 Research and impact strategy

The aim of UWE's research strategy '**Research with Impact**' is "*world-class performance in selected areas of research that meets the needs of our community, a sustainable economy and society and feeds the scholarship and enquiry that underpins our learning and teaching*". (UWE Strategy 2020, see Institutional Statement)). The unit's research focuses on one of the University's four research themes, **Sustainability and Climate Change Resilience**. Our strategic aim continues to be to *increase the quantity and quality of our research, through the development of internal and external collaborations/partnerships, address real-world challenges and enhance our international reputation*. Since REF 2014 we have achieved these aims by making key appointments and strategic promotions, expanding internal funding schemes through substantial investment in laboratory infrastructure and equipment and obtaining external funding. The growth and strength across these themes in both fundamental and applied research are evidenced by refereed papers, through impacts on policy and practice, and through the unit's public engagement activities. Our forward-looking goal is to create a sustainable cycle of internal investment and external income that supports translational research and the development of technological solutions subsequently driving societal and commercial impact.

#### 1.2.1 Plant stress and disease

Work focusing on plant pathology (**Arnold**, **Allainguillaume**, **Wetten**, **Brady**, **Neale**) and plant stress (**Hancock**, **Wilson**) is related to a number of agricultural crops including internationally important crops such as beans and cacao. The expansion of this work during the assessment period was driven by new funding from a range of sources including research councils, charities and industry. Plant pathology research has received significant strategic internal investment in facilities as well as external funding. For example, **Arnold** and **Neale** expanded their BBSRC-funded research on the plant pathogen *Pseudomonas syringae* collaborating with the Universities of Reading, Birmingham, Oxford and NIAB East Malling Research Station (with **Neale**). **Arnold** and **Brady** continued to develop research on the bacteria that cause Acute Oak Decline (AOD) including securing two Partnership PhD studentships, co-funded by Forest Research, Woodland Heritage and UWE. Our plant pathology research was further strengthened by expanding interdisciplinary research on the detection of Cacao swollen-shoot virus (CSSV) (**Allainguillaume**) and the appointment of **Wetten** who secured additional funding for this theme from Cocoa Research UK for a PhD project entitled 'The pathology of Cocoa Swollen Shoot Disease'. Overseas collaborations within plant pathology have been expanded to include **Allainguillaume's** collaborations with Mars UK, the World Agroforestry Centre (ICRAF, Ivory Coast) and the World Cocoa Foundation (Ghana) to develop a CSSV on-site detection system, funded by Innovate UK

Agri-tech Catalyst awards (£370k and £117k). Further overseas collaborations have been established with project funding from the British Council for a Thai PhD student to carry out research in **Arnold's** laboratory on 'The colonization ability of the selected endophytic bacterial inoculation on *Gynura pseudochina* and their effect on phenolic compounds in the plant'.

**Hancock/Wilson** have progressed the investigation of the roles of reactive oxygen species, nitric oxide and hydrogen sulfide in plant stress. More recently, they have investigated the effects of hydrogen gas on plant growth and biochemistry. **Wilson** also investigated the role of the plant stress hormone abscisic acid (ABA) in the alga *Chlamydomonas* and gained insight into how it alters photosynthetic rate and other responses to different light levels via two studentships funded by the Saudi and Brazilian governments. This work also looked at the role of specific glycine rich RNA-binding proteins in mediating ABA responses in both the alga and plants.

### 1.2.2 Agri-Environmental challenges

Our agri-environmental research focuses on challenges that have direct and indirect effects on agricultural systems. **Reynolds** and **Thorn's** NERC-funded work uses an interdisciplinary approach to the management of water catchments impacted by agricultural land use. This includes the development and implementation of technologies, such as novel sensors, for monitoring ground and surface waters impacted by agriculture, and Drinking Water Inspectorate-approved treatment technologies to produce safe drinking water from ground and surface supplies in India. Through a BBSRC grant and partnership PhD with Clear Water Revival Ltd, **Reynolds** and **Thorn** have developed a biofilm technology for the control of waterborne pathogens. **Reynolds** is working with SME Hydrolize Ltd, supported by a two-year Knowledge Transfer Partnership funded by EPSRC and Innovate UK, to engineer and commercialise a biofiltration system for the control of water quality which can be applied to agri-food and aquaculture systems. **Willey's** NERC-funded research on the transfer and effects of radioisotopes in agricultural and unmanaged systems now contributes to food chain radioactivity assessments for humans and wildlife in the UK and, increasingly, internationally. His work helped to significantly reduce the uncertainty in models of environmental transfer used by a variety of regulators and commercial organisations, enhancing confidence in activity thresholds and limits used in regulation of radioactivity in food and the environment. Building on work on biodiversity and functioning ecosystems such as tropical rainforests and oil palm plantations, **Ellwood** developed the birds nest fern as a model system for testing the relationship between biodiversity and ecosystem functioning. This model system is now being used as a conservation tool to ameliorate the effects of converting tropical rain forests to oil palm plantations in Malaysia. This work has strong international ties and moved fundamental science into application in agricultural systems with the aim of restoring biodiversity and functions such as decomposition and nutrient cycling. The challenges of improving environmental sustainability have also been made by newly appointed members of the Unit, **Lintott** and **Stone**. Their research focuses on the impacts of development and changes in agricultural practices on biodiversity and ecosystem functioning using bats and insects as models. Much of their work informs EU and UK legislation, planning and farming practices.

### 1.2.3 Food science and technology

Research has continued to focus on interdisciplinary projects pioneering the development of electrochemical sensor-based technologies (bio-sensors) to address challenges in the organoleptic qualities and nutritional aspects of food products. Recent progress has included finalising the development of a rapid and cost-effective on-line detection system for the pig meat quality defect, boar taint (**Doran and Hart**, supported by two BBSRC Follow-on-Fund grants, an Agriculture and Horticulture Development Board (AHDB) PhD and EU funding). A European patent has been granted for this novel electrochemical sensor system, which will enable the UK and international pig industries to identify and eliminate tainted pork from the food chain thereby maintaining consumer confidence and providing financial benefits to industry. Negotiations have been held with an internationally leading company and agreement on a draft licence has been obtained. Further meat quality research has been carried out on new electrochemical bio-sensors for the measurement of various classes of fatty acids which have strong impact on meat flavour and human health, supported by an AHDB PhD studentship and UWE funding. **Hart** has obtained funding from Unilever to develop simple low-cost electrochemical gas-phase sensors to monitor important target

aromatic compounds of relevance to the consumer goods and pharmaceutical industries. Newly appointed member of the unit, **Stratakos**, is working on the development of strategies to ensure the microbiological safety of the food supply chain and the protection of public health. His work has led to the development of novel antimicrobial methods against foodborne pathogenic bacteria including cold atmospheric plasma decontamination and high-pressure processing (Rangeland Foods Ltd, Auranta Ltd). **Reynolds** work includes the investigation of volatile headspace profiling for the early detection of blackheart disease to better manage potato waste funded by FoodWasteNet, B-hive Innovations Ltd and Innovate UK (KTP).

### 1.3 Impacts on policy, practice and public engagement

#### 1.3.1 Policy

Areas of significant policy impact during the assessment period include improvements to environmental assessments of radioactive emissions (for the Environment Agency) and improvements to predictions of radioisotope transfer from UK nuclear waste repositories (for Radioactive Waste Management Ltd) (**Willey**). A partnership is now in place with the Centre for Environment, Fisheries & Aquaculture Science to develop and apply these findings to the UK's Radioactivity in Food and the Environment report. Changes in policy brought about by **Ellwood's** research include UWE's Policy on Sustainable Palm Oil released in 2018. According to the Roundtable on Sustainable Palm Oil (RSPO) this was the first statement of a change in purchasing policy of any university worldwide. Ultimately, **Ellwood's** research aims to change government policy and management practice in palm oil plantations in Malaysia. **Doran** has been a UK representative, a member of the management committee and a Short-Term Scientific Missions Coordinator in the EU Innovative Approaches for Pork Production with Entire Males (IPEMA) COST Action aiming to facilitate knowledge exchange and impact in sustainable pig production systems in Europe and beyond. **Reynolds** contributed to the Global Knowledge Initiative report 'Innovating the Future of Food Systems'. **Brady** has given annual talks (2015-2020) at Forest Research/DEFRA stakeholder events for 'Future Proofing Plant Health' sponsored by the Rockefeller Foundation.

#### 1.3.2 Commercial Practice

**Reynolds** has been heavily involved in the development of new products, services and innovations for the water sector (treatment and sensing) in partnership with UK technology providers, including Portsmouth Aqua, Bridge Biosystems Ltd and Chelsea Technologies Group. Examples include the development of a disinfection product that has approval for use in the public water supply in the UK by the Drinking Water Inspectorate and Europe via the EU Biocide Product Register. **Hart** and **Doran's** patent for a boar taint biosensor has now been granted and covers 30 European countries. Negotiations are underway with an international company to commercialise this bio-sensor system. Evaluation, commercialisation and knowledge exchange on the boar taint technology has been facilitated by the EU IPEMA COST Action which involves partners from over 20 countries and an EU Tender on the development of new approaches for production of taint-free meat (**Doran**).

#### 1.3.3 Public Engagement

The unit's outreach activities range from interactions with local schools to internationally broadcast programmes. **Arnold/Neale** developed an interactive game, Microbes vs. Plants: An Arms Race, for delivery to students at schools and at science fairs including the Big Bang @ Weston 2018 which attracted 3,000 members of the public. **Willey's** research was featured at the Bristol Festival of Nature 2019 and contributed to exhibitions at the Manchester Festival of Science 2016-2018. **Ellwood** has an oil palm exhibit at the Eden Project, Cornwall, seen by around 1 million people per year. The research of **Arnold** and **Ellwood** was also highlighted in an ITN produced film for the Royal Society of Biology (2018). Part of a series of films on Addressing Global Challenges, this film featured both their research and schools outreach programmes. The work of **Reynolds**' ('Many Bugs make Light Work') was an invited exhibit at the Great British Bioscience Festival 2014, where BBSRC researchers showcased the best of British bioscience in Bethnal Green, as well as at the Cheltenham Festival of Science 2015, with a combined attendance of 50,000 people. **Reynolds'** work has also been widely covered by the BBC ('Costing the Earth', BBC Radio 4 2014/2020 and 'Plastic Planet' and 'War on Plastic', BBC1 2020) and was identified as one of 37 innovations/ideas that are about to change our world (BBC Focus, 2015; BBC Business World 2019; The Engineer,

2019; the Epoch Times, 2020).

Two of the areas mentioned have been submitted as Impact Case Studies. The **nuclear safety** case study (**Willey**) shows how our research is changing the management of the effects of nuclear power on food and the environment. **Safer water** describes how we have improved water quality through the development and implementation of novel technological approaches to monitoring and treatment (**Reynolds and Thorn**).

#### 1.4 Future strategic aims and goals for research and impact

We will continue to build on the success of **Research with Impact** which is further developed in the UWE strategy 2030 (see Institutional Statement). The Unit's research is core to one of the Universities four new Beacons of Excellence, **Sustainability and Climate Change Resilience**. The beacons will drive institutional investment and map to the priorities of a range of key funding streams. These include, but are not limited to, the Government's Industrial Strategy and UK Research and Innovation. Within the Sustainability beacon there several sub-themes, including 'Resources, agri-tech, water security, air quality' which align and support the research within the unit.

Our strategic aim is to maintain and develop the structure of the unit we have developed in recent years in order to expand our key research strands, as well as to pursue novel areas of research and develop new strategic collaborations both internally and externally. We will continue to encourage and invest in interdisciplinary research with impact and promote open science.

##### 1.4.1 Sustained development of research

###### *Plant stress and disease*

Research on the role of bacterial genomic islands in the evolution of plant pathogens (**Neale**) has generated new avenues for research. **Neale** will continue collaborations with NIAB and the Universities of Oxford and Birmingham to understand the triggers of bacterial evolution and how this might be controlled to improve food security. Research funded by Woodland Heritage and Forest Research (**Brady**) has led to the identification of key bacteria involved in Acute Oak Decline (AOD). **Brady** will now continue to develop detection methods for these bacteria to allow early diagnosis and intervention in the field. Research is continuing on the role of reactive signalling molecules in plants (**Hancock**), with a focus on hydrogen sulphide and nitric oxide. This work will continue to embrace collaborations in Spain, Brazil and Croatia, as well as in the UK (Exeter) and has expanded into the possible roles of hydrogen gas in plant growth and post-harvest storage. **Wilson's** finding that ABA induces algae to swim upwards in a light-mediated, negatively geotropic manner will have significant implications with regard to connecting environmental stress responses of photosynthetic organisms to their auxin induced tropisms and will be the subject of future research. **Allainguillemme** and **Wetten's** interdisciplinary research, in collaboration with the IBST, will focus on CSSV both in terms of applied field detection and monitoring but also the fundamental understanding of the biology and lifecycle of the virus. They plan to continue collaborative research with industry (e.g. Mars Wrigley), to develop a biosensor for detection of pre-symptomatic infections by CSSV that is applicable as a field-based system. Following validation of the biosensor, a spin-out company will be set up for its production. The exploitation plan will target sales to cocoa authorities in producing countries, to exporters and to chocolate manufacturers. Users will be able to utilise the detection system in screening programmes at zero cost to farmers, impacting on sustainable cocoa production and the livelihoods of cocoa farmers and workers.

###### *Agri-Environment challenges*

**Lintott and Stone's** research has developed a monitoring strategy enabling the efficacy of green infrastructure interventions to be assessed. Collaborations with project partners including Natural England, the West of England Nature Partnership, and Gloucestershire Wildlife Trust will be sustained to determine how new developments can be sustainably integrated into rural and farming landscapes. These novel modelling techniques will be used to inform strategic planning and development processes to create resilient ecological networks. At a national scale, this will inform Defra's 25 year environment plan for 'net gain' and 'nature recovery networks'. **Willey's** research

on the TREE project established that phylogenetically informed trait prediction is useful in predicting the concentration to which plants take up Technetium-99 and Selenium-75. The aim now is to extend these predictions to other radioisotopes and inorganic contaminants and to 'phylogenetically correct' the understanding of the effects of a range of phenotypes on contaminant uptake.

**Reynolds** and **Thorn** have several mature collaborations with end-users that are near to commercial exploitation. Strong successful partnerships assist the alignment of research priorities that require solution providers and end users (e.g. Agri-tech catalyst calls, Knowledge Transfer Partnerships, overseas development agencies). The unit's model for sustained development of research requires an extensive network of end users and technological providers, as is evidenced by its growing network of collaborations and funding (Industrial, NGOs, UKRI) since 2014.

#### *Food science and technology*

The interdisciplinary research leading to the development of an on-line boar taint detection biosensor has yielded a platform technology which can be adapted to combine multiple sensor types for the simultaneous detection of boar taint, meat fatty acid composition, fat and vitamin content. The aim is now to broaden the scope of the technology for *in situ* monitoring of food quality traits of importance to the food industry. To achieve this, **Hart and Doran** will work with their current collaborators as well as applying for Pathfinder and BBSRC Follow-on Funds and continue our involvement in international consortia. **Stratakos'** research will focus on the identification of agents from natural sources with antimicrobial or anti-virulence effects that can be exploited for the food and feed industries. Work will also aim to develop physical, biological, and natural antimicrobial technologies for food decontamination to decrease the burden from foodborne illness.

#### *1.4.2 Responding to priorities and initiatives*

In alignment with the University's priorities, we will continue to address funder strategic priorities including those of research councils, industry, and charities. For example, our work in plant stress and disease and agri-environmental challenges aligns with the Global Challenges Research Fund (GCRF). The Industrial Strategy Challenge Fund will provide funding opportunities in areas such as transforming food production. More specific initiatives include Action Oak which was recently launched and plans to fund further research to help inform the management of UK oak trees, something that **Brady** is well placed to benefit from. We will continue to develop and capitalise on our strong links with industry and pursue opportunities through Innovate UK and KTPs following the success of **Reynolds** in this area. The strategic appointment of **Turner**, with a background in bioinformatics and the establishment of a bioinformatics computer facility, positions us well in relation to calls that increasingly include aspects of big data. **Turner** will provide complementary expertise to existing members and broaden the range of funded opportunities available to access. We will also continue to access internal investment through University schemes such as the Vice-Chancellor Early Career Researchers (VCECR) awards, VC Challenge Fund, Partnership PhDs and Faculty-funded schemes such as Research Establishment Time for newly appointed academics (in the first 2 years of their appointment), cross-disciplinary collaborative grants, internally funded research time, faculty pilot grants, and cross faculty collaboration. These schemes support staff in their research development at various points in their career and enable research ideas to be developed for external opportunities.

#### *1.4.3 Promotion of research activity, culture and dissemination*

We aim to promote our research activity across the University and beyond. A programme of weekly research seminars is run within CRIB (co-organiser **Stratakos**) which encourages presentations by both academics and postgraduate students. Postgraduate students within CRIB also run their own series of research seminars (section 2). In addition, academic staff and postgraduates can apply for funding from the department to attend national and international conferences, training courses and workshops. As well as traditional publication methods, staff are encouraged to disseminate their research through other multimedia routes including web sites, radio, television, blogs, podcasts and Twitter. We will continue to develop and promote our outreach activities with local schools and at science fairs. Members of the unit collaborate with UWE's Science Communication Unit (SCU) which provides international expertise on public engagement. For example, **Willey** had a joint PhD student with the SCU entitled 'Science Museum Explainer Training: Exploring factors that influence

visitor-explainer interactions' and **Reynolds'** exhibit at the BBSRC Great British Bioscience Festival was supported by SCU staff.

Reflecting the University's commitment to open research, the Faculty has adopted the Open Science FAIR principles (Findable, Accessible, Interoperable and Reusable). To achieve this, we comply with funders requirements for open access publication as well as full compliance with publication of data through the UWE data repository and sharing of materials and protocols.

#### *1.4.4 Investing in impact*

Impact is a central part of our current and future strategy. To lead this activity, we have created the post of Faculty Lead for Enterprise and Impact to (i) explore, develop and drive enterprise opportunities linking research, knowledge exchange, learning, and teaching including the development of a Faculty Enterprise Bursaries scheme; (ii) work with Research Centres, Groups and Institutes to coordinate research-related impact activities; (iii) ensure pursuit of, and effective engagement in, major internal and external initiatives that can promote our connections with individuals and organisations in mutual furtherance of business, enterprise and knowledge exchange. The Faculty has also created Impact Champions whose specific focus is to identify, facilitate and develop impact including that described in the impact case studies but also more broadly. HEIF funds support these activities as well as providing individual support to staff to develop impact from their research including networking events, travel for meetings, exhibitions and working with a range of companies via the University Enterprise Zone (UEZ).

The UEZ comprises four interlinked ventures: Future Space, Launch Space, Health Tech Hub and the Bristol Robotics Lab Hardware Incubator, housed together in the a multi-purpose building. Future Space is a business incubator for SMEs in high-tech areas including health technologies and biosciences which currently supports approximately forty businesses by providing accommodation, lab facilities, business support, and opportunities for interdisciplinary collaboration with University research teams. The UEZ has been used by, for example, **Reynolds** who leads a KTP worth £200k in collaboration with Clearwater Revival, a company located within the UEZ to design, develop and fabricate a small-scale, low-cost, low-energy microbial biofilter system. The Health Tech Hub is also providing researchers with the capacity and connections to develop partnership projects. For instance, engineering expertise and equipment available from the Health Tech Hub and IBST contributed in enabling **Allainguillaume** to gain two (£487k) InnovateUK grants to work in collaboration with Mars Wrigley and the World Agroforestry Centre (ICRAF) to develop and commercialise an in-field sensor for the detection of cacao swollen shoot virus.

#### *1.4.5 Research governance*

The unit continues to maintain and develop our research governance in line with internal and external expectations. For example, all Principal Investigators are required to complete a faculty Research Governance (RG) Record which captures information on all aspects of governance appropriate to their project, including the use of endorsed risk assessments. Staff from the unit are members of both the University and Faculty Research Ethics Committees, and University-wide committees that cover Biological Safety, Animal Welfare and Ethics (**Hancock**, Chair), Genetic Modification Safety (**Turner**, Chair) and the use of Human Tissue (**Hancock**). Policy is overseen by a University Research Governance Manager and is driven in the faculty by an academic lead (**Hancock**) who chairs a Good Research Conduct Group to support and ensure delivery of good practice in line with the Concordat to Support Research Integrity and the University's Code of Good Research Conduct. Individual projects must secure ethical approval (if required), from the Faculty Research Ethics Committee. All research data collection must conform to the GDPR2018 regulations and is expected to have a Data Management Plan. Regular training sessions are put in place in the Faculty to ensure all staff are aware of RG requirements and are kept up to date with new regulations and procedures.

## Section 2. People

### 2.1 Staffing strategy

Our staffing strategy has been to ensure growth and succession planning in key areas of research excellence. To achieve this we have (i) invested in the appointment of high-quality staff in key strategic areas, (ii) supported research career development of all staff in the unit and (iii) promoted staff from within the unit.

#### 2.1.1 Internal promotions

All staff have an annual Performance and Development Review (PDR) to review their work and support their career development. During the REF period, **Doran** was promoted to Associate Dean (Research) but continues to research actively in the unit; **Hancock** was promoted to Professor of Cell Signalling; **Willey** to Professor of Environmental Plant Physiology; **Allainguillaume** and **Ellwood** to Associate Professor. **Turner** was promoted to Senior Lecturer and has since led the establishment of a bioinformatics suite. He is actively involved in the development of bioinformatics pipelines and training courses which will benefit unit members and those in biomedical sciences. Newly appointed staff **Brady** and **Neale** have been promoted from Research Associates to Research Fellows. **Brady** has extensive expertise in bacterial taxonomy and her work focuses on research into acute oak decline as well as supporting other staff in molecular taxonomy. **Neale** is a molecular plant pathologist who has collaborated with **Arnold** on three BBSRC grants. During the assessment period, **Thorn** has been promoted from Research Fellow to Senior Lecturer and subsequently to Associate Professor, further demonstrating a strong commitment to career development of promising researchers within the unit

#### 2.1.2 External appointments

Our external recruitment strategy has been to target specific areas of research to strengthen and expand our research base. In the area of plant stress and disease **Wetten** (University of Reading) was appointed to strengthen international research on cocoa and the devastating Cacao swollen shoot disease in collaboration with **Allainguillaume**. The appointment of **Lintott** (University of Exeter) and **Stone** (University of Bristol) brings expertise in investigating how modern challenges, such as urban expansion, renewable energy and fragmented landscapes, impact wildlife and agricultural practice, strengthening our environmental challenges theme. **Stratakos** was appointed as part of a major institutional initiative to invest in areas of strength and vitality. As a Wallcourt Fellow in Sustainable Agri-Food Production, his appointment is 50% ring fenced for research time for the first three years. **Stratakos** adds extensive experience in developing novel strategies to ensure the microbiological safety of the food supply chain and the protection of public health. Additional appointments have been made recently to build further capacity and expand research into new areas over the next period, including Akpiri (Birmingham), Fernandez (Bristol), Hindle (Sheffield), Sargeant (Plymouth) and Vafidis (Cardif).

### 2.2 Staff development

Newly appointed and promoted staff are supported by: (i) mentoring by more experienced staff to support their transfer to the university, aid the development of research capability and to help with career progression; (ii) access to funds provided for dedicated research time and to the Faculty Research Establishment scheme which provides ring-fenced time for targeted research activities; (iii) specialist training and mentoring to support bid preparation and project management.

Early Career Researchers (ECR) can apply for competitive funding via the Vice Chancellors (VC) ECR awards aimed at developing the University's most promising researchers, supported by a senior staff mentor. **Brady** (£14k), **Lintott** (£15k), **Stone** (£15k) and **Turner** (19k) have all received VCECR awards during this period which has led to further funding being obtained (**Brady** - Woodland Heritage; **Lintott** - NERC). Specialist training and mentoring are provided from senior academic staff and Research, Business and Innovation (RBI) to support bid preparation, project management, financial and risk management. Demonstrating our commitment to promising researchers, Faculty bridge funding has been used to retain promising post-doctoral researchers

(**Brady, Neale**). Competitive financial support is also available to established researchers for pump priming of new initiatives, for example **Ellwood** received internal funding (£20k) for a new collaboration with the Science Communication Unit and University of Oxford to create a digital insect repository. Staff can also apply to the VC Accelerator Programme for Mid-Career Academics and the VC Interdisciplinary Research Challenge Fund to develop new interdisciplinary teams working on early stage research projects and/or applying for external funding

The principles of the *Concordat to Support the Career Development of Researchers* (updated 2020) are actively implemented. Consequently, UWE has held the European Commission's HR Excellence in Research award since 2012. An updated Concordat action plan was produced for 2018-2020 led by **Hancock** who is also chair of UWE's Researchers' Forum Planning Group, a pan-university group with representation from research staff across the institution with the aim of supporting career development. It runs two dedicated events each year as well as feeding into UWE's staff development provision, supported by a Skills Development Officer positioned in RBI.

### 2.3 Research students

The unit aims to provide an exemplary training, support and learning environment for its postgraduate research (PGR) students drawing upon the UWE Graduate School and the PGR Code of Practice. During the assessment period there were 17 student completions. PhD students have been externally funded from a wide range of sources including the AHDB, NERC, Woodland Heritage, Royal Horticultural Society, Portsmouth Aviation Ltd, Chelsea Technologies Group and Libyan, Saudi, Brazilian and Kuwaiti governments, as well as through competitive University funds. This includes a new initiative to support Partnership PhDs, where funding is jointly provided by an external non-academic organisation and by the University (typically 50% each). Partnership PhDs have been obtained by **Reynolds** (£40k from Clear Water Revival Ltd / Hydrolyze Ltd, £40k from Chelsea Technologies Ltd, £60k from Creo Medical Ltd, £80k Portsmouth Aviation), **Arnold** (2 x £40k from Woodland Heritage, £40k from the Royal Horticultural Society), **Steer** (£42k from the Archipelagos Institute of Marine Conservation and £21k from Operation Wallacea), **Lintott** (£38k from National Grid) and **Stone** (£34k from Natural England). CRIB has also been appointed as an associate partner to the BBSRC SWBio Doctoral Training Programme.

PhD students are supervised by a team comprising a Director of Studies and one or more supervisors, often from industry (e.g. Sun Chemicals, JSR Genetics, Chelsea Technologies Ltd, Portsmouth Aviation Ltd); research institutes (e.g. Forest Research); levy boards (e.g. AHDB); other HEIs (e.g. Reading, Bristol) or health bodies (e.g. North Bristol NHS Trust).

All PhD students are members of CRIB and expected to attend the programme of research seminars given by internal and external speakers, as well as to present their work as internal speakers at the Annual Postgraduate Forum, as part of a 30-credit Research Training and Professional Development module, and to participate in the annual showcase of research activity within CRIB. PGRs are also required to pass a further 30 M level credits. This is often from a 'Research in Contemporary Context' module which aims to embed personal, professional and career development within research degree programmes via a process of research-based learning, but can be any module that develops attributes mapped to Vitae's Researcher Development Framework. This suite of short courses includes training on specific requirements of the doctoral journey (progression exam, progression review, final viva) as well as training courses on, for example, academic writing and presentation skills.

Laboratory research students have dedicated bench space and individual workstations in the designated postgraduate centre, working alongside post-doctoral researchers and research technicians. All students are provided with a laptop. The Faculty invested £0.25M in the postgraduate centre to include individual workspaces (2018). All PGR students are members of the University Graduate School (**Willey**, Director) which provides a supportive environment from application through to graduation, offering a range of bespoke services to meet individual needs. As well as an extensive skills development programme of workshops to develop transferable skills, the Graduate School provides residential and networking events and access to regional and national



support schemes (see Institutional Statement). All PGR students are invited to apply for support to attend national or international conferences by the Faculty Research Degrees Committee (FRDC). Although a competitive process, most PGRs who apply get support, up to £1,000 per trip, towards registration, travel and accommodation. Students of **Arnold**, **Ellwood** and **Reynolds** have been recipients of this scheme.

The PGR community expanded with the introduction of an MRes in Applied Sciences in 2017. As part of the MRes, students take modules on 'Research Training', a 'Professional Development Portfolio' and 'Research in Theory and Practice' as well as an extended (120 credit) project carried out within one of our research teams. Several MRes students have gone on to undertake PhDs including students of **Allainguillaume** (at Exeter University) and **Arnold** (at UWE).

#### 2.4 Equality and diversity

Equality and diversity are key values of both the unit and University; all staff undertake an online equality training course every two years. Additional support for female researchers is provided through the University Women in Research Mentoring Scheme (**Arnold**, mentor) to strengthen their leadership skills and research portfolios in order to achieve senior research positions. Work undertaken to support female researchers resulted in the Department's Athena SWAN Silver award in 2020. **Brady** and **Neale** have both had two periods of maternity leave during their employment and are now 0.8 FTE, reflecting a flexible approach to the working conditions of new parents. The University was again listed in the Stonewall Top 100 employers in 2020.

Unit staff have been identified as having significant responsibility for research, as independent researchers in strict accordance with the University's Code of Practice. Outputs have been selected based on their quality as determined through a peer review process with no expectation about the number of outputs any one individual contributed to the submission. Where it was necessary to choose between a small number of outputs with the same quality score to reach the required total, the distribution of outputs between individuals and across the subject areas of the submission were taken into account.

### Section 3. Income, infrastructure and facilities

#### 3.1 External funding

The unit's strategy is to target funders that support our strategic goal to continue to develop and invest in our three key research strands. To do this we target national and international funding sources from a range of funders such as research councils, charities and industry. The unit's external research funding in this period totals £2.8m (see REF4b). Examples of external funding have come from Research Councils (BBSRC; £929k **Arnold**, £640k **Doran**, £289k, **Hart**, NERC; **Reynolds** £343k, **Willey**, £375k), UK Central government (Innovate UK; £487k **Allainguillaume**), UK Based Charities (Woodland Heritage, The Gilchrist Educational Trust, Frank Water, Westcountry Rivers Trust), UK industry (Portsmouth Aviation Ltd, B-hive Innovations Ltd, Mars Chocolate UK Limited, Unilever, Chelsea Technologies, Creo Medical, Hydrolize Ltd, Clear Water Revival Ltd, Centrego Ltd), EU Industry (European Cocoa Association) and AHDB. PhD studentships have been funded by AHDB (**Doran & Hart** £70k). Partnership PhDs have been funded with Woodland Heritage (**Arnold**, **Brady**), Portsmouth Aviation Ltd, Creo Medical, Chelsea Technologies (**Reynolds**), National Grid (**Lintott**). PhD students have been funded externally from the Libyan and Kuwaiti governments (**Wilson**).

#### 3.2 Internal funding

The unit's internal strategic investment for research and impact in this period totals £1.33m. This includes investment in newly appointed staff and additional research workload. Staff have been successful in obtaining funding from internal University sources including the VCECR fund, Partnership PhDs and VC Interdisciplinary Research Awards. New in this period, the VC Interdisciplinary Research Challenge Fund was created to enable researchers to reach beyond

their centres, departments, and faculties to develop exciting new interdisciplinary research with colleagues working in different fields. **Reynolds** obtained two VC awards in collaborations with colleagues in the Faculty of Environment and Technology, one for a project investigating drinking water and airborne microplastics (£24,934) and one to investigate the use of bioelectrochemical filters for clean electricity and resource recovery as fertiliser (£25k). **Thorn** and **Willey** obtained a VC award (£25k) for a microbial fuel cell based hydroponic production system for food crops.

### 3.3. Operational infrastructure supporting research

Staff are supported in a range of ways such as Research Establishment and Research Progression time (outlined in section 2). In addition, all staff can apply for workload to support research. A dedicated technical team supports laboratory research. As part of the of the Centre for Research in Biosciences (CRIB), a management group addresses strategic research and administrative aspects and leverages an advisory board comprising 19 representatives from academia, industry, healthcare and government organisations to advise on research directions, external funding, knowledge exchange, partnership opportunities and enhancement of impact. The Associate Dean for Research (**Doran**) has oversight of Faculty research and enterprise activities and advises the Pro Vice-Chancellor on strategic developments to support the aims and objectives of the Faculty. The Associate Dean is supported by the Faculty Research and Knowledge Exchange Committee that monitors the development and implementation of research and knowledge exchange across the Faculty.

A dedicated Faculty Director of Postgraduate Research Studies liaises with the Centres to deliver PGR training. An additional Lead for Postgraduate Research Funding (0.2 FTE) enables a coordinated response to external PGR funding opportunities. The University's Research, Business and Innovation (RBI) service supports all research activities, providing support to identify research funding, bid preparation, professional development, business engagement, IP and technology transfer and grant administration.

### 3.4 Specialist infrastructure and facilities supporting research

The University has recently invested over £7M in 6,500 m<sup>2</sup> of Laboratory infrastructure to support research. This has allowed realignment of research groups and provided dedicated space for staff including, for example, a dedicated laboratory for plant science research. This has brought together the groups of **Arnold, Allainguillaume and Wetten**, facilitating greater collaboration in plant stress and disease. The new infrastructure includes: an electron microscopy suite; molecular biology laboratories; volatile analysis laboratory; analytical instrumentation; electrochemical sensor laboratory; microbiology laboratories; and a bioluminescence suite. In addition, a new bioinformatics hub (led by **Turner**) to support research training and teaching, with a dedicated server and 12 workstations, has been developed (£77.7K). The "Envirotron" environmental greenhouse facility (£1M; 204.8m<sup>2</sup>) contains several different sections including temperate and tropical areas, supporting plant and agri-environmental research. It is used by several research groups (**Allainguillaume, Arnold, Ellwood, Wetten, Wilson, Willey**), provides a state-of-the-art teaching facility for both undergraduate and postgraduate students and complements our existing plant growth cabinet facilities.

As noted above, research in the unit benefits from the University Enterprise Zone (£16.5M; 4,100m<sup>2</sup>) established as one of four in England, match-funded by the Department of Business, Innovation and Skills and the West of England Local Enterprise Partnership (LEP). Within the UEZ, 'Future Space' offers flexible support for business to grow and develop, providing specialised workspaces and laboratory infrastructure, and 'Launch Space' assists entrepreneurial students and academics. Co-located is the Health Technology Hub, funded through the European Regional Development Fund and LEP (£5M), which provides commercial and advanced technical support to life science start-ups and currently hosts more than 30 companies, many in the life science sector: Atlas Genetics; CPP Analytics; DoDxAct; eXmoor Pharma Concepts; Merck Serono, and Pertinax.

**Section 4. Collaboration and contribution to the research base, economy and society****4.1 Examples of collaboration within academia**

The unit takes a proactive approach to promoting excellence, collaboration and impact in research and strongly encourages collaboration with both international and UK universities.

*4.1.1 International collaborations:*

**Arnold:** visiting Fellow at the Department of Botany, University of Kelaniya, Sri Lanka.

**Ellwood:** collaborated with Professor Harald Schneider from the Xishuangbanna Tropical Botanical Garden in China, funded by the Chinese Academy of Sciences.

**Willey:** has developed key partnership and reciprocal visits with the Belgian Nuclear Research Centre in Mol, Belgium.

**Allainguillaume:** has a partnership with cocoa director Dr Loor of the Instituto Nacional de Investigacion Agropecuaria in Ecuador, who is an academic supervisor for a UWE PhD student.

**Hancock:** is a science advisor for University of Osijek, Croatia.

**Stratakos:** hosted a visiting researcher from Technological Institute of High Studies of Acayucan, Mexico.

**Brady:** collaborates on several taxonomy projects with University of Pretoria, South Africa and Cornell University, USA.

**Reynolds:** has projects and partnerships with researchers from institutions in India; Bose Institute (Kolkata) Indian Institute of Science Education and Research (Kolkata) Indian Institute of Technology (in Guwahati, Roorkee and Patna) and the Institute of Life Sciences (Bhubaneswar). Other international collaborations include the University of Havana (Cuba), Umea University (Sweden) and the Federal Institute of Goiás (Brazil).

**Turner:** collaborates on phage research with KU Leuven, ETH Zurich and the DSMZ, Germany.

*4.1.2 National collaborations:*

**Arnold, Brady & Neale:** on bacterial pathogen evolution (BBSRC) with the Universities of Oxford, Birmingham and Reading and with NIAB East Malling Research station and Reading University on cherry pathogens (BBSRC).

**Ellwood:** with Oxford University to create a digital insect repository.

**Lintott:** Bristol University to develop an eDNA-based methodology for detecting the presence of bat species. With Sussex University to determine the effectiveness of bat mitigation strategies. With Exeter University to assess the impact of renewable energy on wildlife populations.

**Willey:** As part of the TREE project, with academics at Universities of Nottingham, Salford, Stirling, Portsmouth and Plymouth.

**Stone:** has ongoing collaborations with the Universities of Southampton, Nottingham Trent and Sussex.

**Stratakos:** has ongoing collaborations with Queen's University Belfast on isolating bioactive substances from seaweed and assessing the potential of insects in animal feed.

**Reynolds:** has collaborations with the Universities of Bristol, Manchester, Birmingham, Centre for Ecology and Hydrology (NERC), British Geological Survey, University College London, University of Edinburgh focusing on water quality, antimicrobials and global health.

**Turner:** collaborates with academics at the Quadram Institute, University of Leicester and Public Health England.

**4.2 Examples of collaboration with stakeholders beyond academia**

A key strength of the unit is the combination of fundamental and applied research expertise facilitated through collaboration with non-academic stakeholders in a variety of ways, as evidenced by:

**Allainguillaume & Wetten:** with Cocoa Research UK and Mars Wrigley funding for studying Cacao Swollen Shoot Virus.

**Arnold:** with a PDRA and two partnership PhD students funded by Forest Research and Woodland Heritage on Acute Oak Decline.

**Lintott:** has strategic partnerships with Bat Conservation Trust, Sustrans, Bristol City Council, Public Health England, Scottish Government, West of England Nature Partnership, Forest Research.

**Reynolds:** has strategic partnerships with West Country Rivers Trust, Frank Water, Water Harvest, British Geological Survey, Centre for Hydrology and Ecology, Environment Agency, Bristol Royal Infirmary, Public Health England and industrial engagement with Creo Medical Ltd, Chelsea Technologies Group, Portsmouth Aqua, Branston and B-Hive Innovations, Centrego Ltd, University Hospitals Bristol (Children's Burns Centre), Clear Water Revival, Bridge Biotechnology, South West Water Ltd, Altered Carbon Ltd, Hydrolize Ltd, Robert Scott Ltd, SADABE and the Avon and Somerset Wildlife Trust.

**Willey:** has collaborations with the Environment Agency and Radioactive Waste Management Ltd. Partner organisations for the TREE project include International Atomic Energy Agency, Food Standards Agency, Scottish Environmental Protection Agency, National Institute of Radiological Sciences Japan, International Commission for Radiological Protection and the International Union of Radioecology.

**Hart and Doran:** have collaborations with AHDB, JSR Genetics, Unilever plc as well as international pig breeding companies in EU Countries and Ukraine.

**Stone:** has long term collaborations with the Department of National Parks and Wildlife Malawi, Natural England, Bat Conservation Trust, Vincent Wildlife Trust, CSA Environmental, Government of Malawi and Bat Conservation International.

#### 4.3 Examples of externally recognized roles and activities

Reflecting the expertise present within the unit, members of APFE are involved in a range of grant awarding bodies, act on journal editorial boards, take part in the governance of scientific societies, are members of advisory boards and conference organizing committees and have been invited to deliver research talks both internationally and nationally.

##### 4.3.1 Grant awarding bodies

**Arnold:** is a core member of BBSRC Research Committee B – Plants, Microbes, Food and Sustainability.

**Doran:** is a member of BBSRC Follow-on Fund Committee, a member of the BBSRC Bioscience Skills and Careers Strategy Advisory Panel, the Executive Group, Bristol Health Partners, a coordinator of Short-Term Scientific Missions (EU COST Action) and until 2019 was a member of the Expert Panel of the European Food Standards Agency.

**Reynolds:** is a panel member for proof of concept calls for National Biofilms Innovation Centre (BBSRC), Biotechnology Risk Assessment Grants program (USA), Hong Kong Research Council, Chair of Biotechnology Funding Panel at Fundação para a Ciência e a Tecnologia (Portugal) and a NERC peer review college member.

**Stratakos:** is an expert team member for the National Science Centre, Poland.

Staff are also recognised for their expertise and review for a number of funding bodies: BBSRC (**Arnold, Allainguillaume, Hancock, Turner, Willey, Wilson**); NERC (**Ellwood, Lintott, Reynolds**), Sêr Cymru (Business Wales) COFUND fellowships (**Allainguillaume**), EPSRC (**Reynolds**), Global Challenges Research Fund (**Reynolds**), Agence Nationale de la Recherche (France, **Lintott**); Agropolis Research Grants for Cacao research (France; **Allainguillaume**); Slovenian Agency for Research grant scheme, Belgian National Research Foundation "Fonds Wetenschappelijk Onderzoek" and Research Council of K.U. Leuven (**Doran**).

##### 4.3.2 Membership of Editorial Boards

**Arnold:** Plant Pathology and PLOS One.

**Hancock:** PLOS One, Frontiers in Plant Science, Plant Cell and Environment and Reactive Oxygen Species.

**Reynolds:** Journal of Sensing and Imaging, Sensors and the Water and Environment Journal.

**Willey:** International Journal of Phytoremediation, Water, Air & Soil Pollution.

**Turner:** Section editor for MDPI Viruses.

**Stratakos:** Topic Editor for MDPI Applied Sciences

#### 4.3.3 *Involvement in the governance of scientific societies, membership of advisory boards and conference organizing committees.*

**Arnold:** was President of the British Society of Plant Pathology (2019), Microbiology Society representative for the UK Plant Sciences Federation and a programme committee member for America Society of Microbiology (ASM) annual meetings 2018-19.

**Ellwood:** was a member of the Eden Project Science Steering Committee and an invited symposium lead for the ASM 2019 annual meeting.

**Hancock:** was an organising member of 6<sup>th</sup> Plant Nitric Oxide International Meeting, Spain and 7<sup>th</sup> Plant Nitric Oxide International Meeting, France.

**Hart:** is the Honorary Secretary of the Electroanalytical Sensing Systems group, Analytical Division, Royal Society of Chemistry, a Scientific Committee Member of the Electrochem 2016 International Conference organised by Royal Society of Chemistry and Society for Chemical Industry.

**Willey:** is Chair of the UK Co-ordinating Group on Environmental Radioactivity (COGER).

**Doran:** is a member of the European Association for Animal Production Working Group on Boar Taint, and a member of the Management Group and Coordinator of Short-Term Scientific Missions for the EU IPEMA COST Actions.

**Stone:** is a member of IUCN Hyaena and Bat Working Groups and organised the Rufford Conservation Conference, Malawi, 2019.

**Stratakos:** is a member of the publications committee of the Institute of Food Science and Technology.

**Turner:** is Vice-Chair of the Bacterial and Archaeal Viruses Subcommittee for the International Committee on the Taxonomy of Viruses (ICTV) and was an invited member of a discussion group on emerging issues in virus taxonomy hosted by ICTV with support from the Wellcome Trust.

**Reynolds:** was Chair of the Tryptophan2020 Conference and member of the International Scientific Committee for AQUA360, 2020.

#### 4.3.4 *Invited speakers.*

**Arnold:** was a keynote speaker at Pseudomonas 2019 Maylasia and the 50<sup>th</sup> Anniversary Congress of the Southern African Society for Plant Pathology in South Africa as well as giving invited presentations at the University of Jerusalem, Israel and University of Kelaniya, Sri Lanka.

**Ellwood:** was an invited seminar speaker at the University of Reading and was invited to attend the 15<sup>th</sup> Annual Roundtable on Sustainable Palm Oil conference in Indonesia (2017). **Allainguillaume** presented at the Centre National de la Recherche Scientifique, International Symposium on Cocoa Research, Lima, Peru.

**Lintott:** presented at National Bat Conference, Britbats, 2018.

**Willey:** presented at the 'Radioactivity and the Environment' programme science meeting at University of Bristol, South West Nuclear Hub seminar (2019).

**Reynolds:** was a keynote Speaker at European Geosciences Union General Assembly (University of Umea, Sweden), the Annual Autumn Research Symposium, Abisko Scientific Research Station 2019 and was Chair of 'Pitch at the Palace', Bristol, 2017.

**Doran:** was an invited speaker for the EU workshop on meat quality detection in 2018, Monells, Spain.

**Stone:** was Guest Speaker at the European Symposium for the Protection of the Night Sky, Co. Mayo, Ireland (2019).

**Stratakos:** was an invited speaker for the workshop 'Understanding drivers of antimicrobial resistance in the food chain', Guangzhou, China, 2019.

**Brady:** gave invited presentations to the Action Oak meeting at Kew Gardens, 2019 and SfAM Applications of Plant Pathology, 2018.

**Turner:** gave an invited presentation at the Oxford Bacteriophage Conference, 2018.