

<b>Institution:</b> Aberystwyth University
<b>Unit of Assessment:</b> 6: Agriculture, Food and Veterinary Sciences
<p><b>1. Unit context and structure, research and impact strategy</b></p> <p><b>Context</b></p> <p>The Institute of Biological, Environmental and Rural Sciences (IBERS) brings together a unique assembly of life scientists, state-of-the-art research facilities and collaborative networks, to address some of the most significant challenges of the 21<sup>st</sup> century on sustainable agriculture, climate change, one health, and biodiversity. The academic disciplines of agricultural, plant and zoological sciences have been taught and researched at Aberystwyth University (AU) since 1874, and in 2019 we celebrated 100 years of plant breeding. AU therefore has a long history of carrying out both the underpinning science and it's translation to create real world impacts.</p> <p>IBERS was created in 2008 with the merger of two departments of AU (Institute of Biological Sciences and the Institute of Rural Sciences) with the BBSRC Institute for Grassland &amp; Environmental Research (IGER). In REF 2014, IBERS made joint submissions with Bangor University via "The Biosciences, Environment and Agriculture Alliance" (BEAA) to both UoA 6 and UoA 7. Funding for BEAA ran from 2006 to 2015 and established collaborations are still ongoing. In REF 2021, IBERS is being returned wholly to UoA 6 as a departmental unit. IBERS ambition is to develop research strengths that align with our strategic aims by focusing on the four societal challenges of:</p> <ol style="list-style-type: none"> <li>1. Sustainable agriculture &amp; healthy food.</li> <li>2. Climate change adaptation &amp; mitigation.</li> <li>3. Interconnected animal &amp; human health.</li> <li>4. Exploring &amp; conserving biodiversity.</li> </ol> <p>In each case, we are creating the expertise, infrastructures and collaborative networks for conducting excellent research and delivering impact. IBERS and its research portfolio have therefore evolved since the REF 2014 submission particularly in the areas of diet and human health, and in animal health. For example, since REF 2014 IBERS expanded to include the Department of Sports &amp; Exercise Science (previously submitted to UoA 26) and formed a School of Veterinary Science supported by a Veterinary Research Cluster.</p> <p>As the largest academic unit in AU, and located within the Faculty of Earth and Life Sciences, IBERS is fundamental to the delivery of the University research and innovation strategy. The Department has benefited from substantial capital investment by the University and through national programmes via UKRI, the Welsh European Funding Office (WEFO) and HEFCW. These investments ensure the long-term sustainability of IBERS research platforms and our ability to attract new research income, staff and PhD students. IBERS has also benefitted from the Sêr Cymru programme, a Welsh Government initiative to support research and attract world-class talent to Wales. Within the REF 2021 period we have built on our collaborative networks in Wales with support from Sêr Cymru, in the UK through participation in two new doctoral training centres, and internationally through strategic partnerships to build community resources, including for forage grasses, clover, oats and Miscanthus. Since REF 2014 major developments strengthening the research environment in IBERS include:</p> <ol style="list-style-type: none"> <li>1. Establishment of the Aberystwyth School of Veterinary Science (the first in Wales) and the opening of VetHub and Sêr Cymru Veterinary Research Laboratories to provide state-of-the-art immunology and containment level 2 and 3 facilities for working on bovine tuberculosis (TB) and other infectious diseases.</li> <li>2. Opening of the £40M AberInnovation campus with biorefining, advanced analytical, and future food facilities.</li> </ol>

3. Opening of a new, purpose-built seed biobank to curate an internationally important collection of over 35,000 accessions of forage grasses, clovers and energy grasses, and of a crop seed processing unit to support plant breeding.
4. Taking on of a new 50-year lease for Trawscoed farm from BBSRC and expanding an existing lease to cover 680 ha at the Pwllpeiran Upland Experimental Platform from Welsh Government, to continue our pioneering grassland science across a wider range of environments.
5. Participation in two new doctoral training centres (BBSRC FoodBioSystems DTP, and UKRI Food Systems CDT) to train the next generation of food and agricultural scientists.

### **Research strategy**

IBERS research strategy is to develop the people, facilities, academic networks, and stakeholder relationships that creates a vibrant research environment capable of tackling some of the key challenges of the 21<sup>st</sup> century. To do this IBERS research spans fundamental, strategic and applied sciences to create a translational research pipeline. Our strategy supports an assembling of research expertise that allows us to study from field to fork and human health, and from catchment to coast and environmental impacts. IBERS therefore has the research base to deliver on its ambition to bring about real-world impacts that deliver benefits to people and planet. This has then allowed us to take on key societal challenges spanning sustainable agriculture, climate change, animal and human health and biodiversity (Table 1). This builds on our REF 2014 aim to convert 21<sup>st</sup> century grand challenges into sustainable and prosperous opportunities for society. We recognise that to tackle such significant problems also requires collaboration and IBERS has extended its partnerships both within AU and externally.

We have progressed our REF 2014 strategy by making successful research funding applications to UKRI and EU, and built the AberInnovation Campus (referred in REF 2014 documentation as an Innovation and Diffusion Campus) to accelerate the translation of our science. We have further implemented our strategy by applying for, and linking, revenue funding to utilise the AberInnovation facilities through the BEACON and Future Food projects. AberInnovation is also helping us to drive an enhanced knowledge exchange and commercialisation culture within IBERS with industry (e.g. Germinal, Terravesta, Nemesis Biotech, and spin-out ARCITEKBio) funded scientists now located on campus. We have expanded our bioeconomy research including through BEACON (incorporating the Centre for the Bioeconomy) and by being one of the founding members of BioPilotsUK. We have delivered on our objective in REF 2014 to expand the National Plant Phenomics Centre (NPPC) including by establishing an altitudinal challenge gradient at four instrumented sites on two of the University farms. The NPPC has also increased its involvement in international projects and regularly hosts visiting researchers. We have achieved our aim to increase the diversity of plant accessions held, including by leading expeditions to make targeted collections of under-represented species and from under represented environments. In addition, we met our REF 2014 objective to significantly enhance capacity and accessibility through the building of a new £6M seed biobank facility. We have also delivered on our long-term aim for IBERS to participate in UKRI doctoral training programmes through our involvement in the BBSRC DTP in FoodBioSystems and the UKRI Food Systems CDT.

Table 1: The four Societal challenges, and the associated research groupings, which underpin IBERS Research Strategy.

1. Sustainable agriculture & healthy food	2. Climate Change adaptation & mitigation	3. Interconnected animal & human health	4. Exploring & conserving biodiversity
Sustainable grassland agriculture	Greenhouse gas reduction in livestock agriculture	Parasitology and helminth control	Conservation and management of natural resources
Phenomic science & controlled environment agriculture	Crops for sustainable energy and materials	Bovine TB detection, protection and control	Understanding and restoring ecosystems and their services
Plant breeding for the future	Natural resources and the circular economy	Epidemiology	Ecology and evolution, populations to ecosystems
Diet and health	Marine environmental impacts and remedies	One health and zoonotic diseases	

Sustainable agriculture & healthy food. IBERS has collected and developed unique germplasm resources for over a century and these are subjected to powerful phenotyping and genotyping technologies to understand biological mechanisms of yield quantity, quality and the stability of both. Our approach is holistic with plant phenotyping spanning vegetative and reproductive features (Armstead, Bosch, Doonan, Thorogood), quality (Allison, Lister, Moorby, Kingston-Smith, Williams C) and post-harvest preservation (Griffith, Winters). Studies of wild accessions, breeding lines, and varieties are carried out, in both controlled environments and the field, for science discovery and to inform the development of new crop varieties (Cowan, Hegarty, Yadav). Two thirds of agricultural land in the UK (and globally) is grassland, and IBERS research addresses the twin-challenge of production and ecosystem service delivery (Fraser, Marley, Scullion). In grassland science, IBERS is unique in the UK and one of few institutions worldwide that combines the plant, animal, soil, microbiology and environmental sciences necessary to study this complex system in one physical centre. We aim to develop new methods of plant breeding and recombination control (Jones H, Lloyd, Philips), and selection indices to better predict traits (Davey C, Skøt). We recognise the opportunities provided by sensors, robots and instrumentation and aim to develop these both as tools for phenomic science (Gay, Doonan) and for improving crop and animal productivity (Williams M) including on extensive hill enclosures (Fraser). Our research requires powerful underpinning statistics, crop modelling, bioinformatics and data analysis which we have developed in house (Davey C, Fernandez-Fuentes, Sanderson, Scott, Swain) and also through collaboration (e.g., with Earlham and University of Aberdeen). Delivering on the Eatwell Guide is a significant challenge for both the food sector and consumers, and we have pioneered research on dietary intake biomarker technology to help understand the links between food composition and health outcomes (Beckmann, Draper). In addition, through the addition of sports and exercise science expertise, we are now studying the impact of food nutritional quality (Adams, Wootton-Beard, Yadav), exercise (Arkesteijn, Villagra Povina) and interactions between them (Thatcher, Wallace). As part of our strategy we are applying our expertise to emerging trends in agriculture including vertical farming (Gwynn-Jones, Robson), and alternative protein sources (Gallagher, Kingston-Smith, Wonfor).

Climate Change adaptation & mitigation. Climate change and extreme weather events present a significant threat to agriculture and particularly to perennial crops and this is a significant focus in

the BBSRC Resilient Crops Strategic Programme. We also recognise the need for agriculture as a sector to become net zero by 2040. IBERS is researching mechanisms to reduce greenhouse gas emissions from ruminant livestock (Kingston-Smith, Moorby, Fraser, Wonfor) as well as land based renewable energy and greenhouse gas removal including from perennial biomass crops (Clifton-Brown, Donnison, Robson) and subsurface energy and geologic carbon storage (Edwards). In marine environments, we are exploring eco-engineering approaches to enhance coastal defences and offshore renewable energy structures (Ironsides, Shaw, Wilcockson). In addition, our research is enabling the prediction of changes in organism distributions in response to climate change scenarios including for the sustainable management of fished species (Ironsides, McKeown, Shaw). Our approach on BioEnergy has expanded from the use of biomass as a fossil fuel substitute toward its role for greenhouse gas removal in combination with Carbon Capture and Storage (BECCS). In Miscanthus, we recognise the urgency to accelerate variety development through deployment of genomic prediction (Davey C) and utilisation of diverse germplasm (Huang). Novel bacterial endophytes are also being identified (Farrar) with the potential to promote plant establishment, growth and resilience especially on marginal land (Jensen). The bioeconomy requires the bringing together of multiple disciplines. IBERS has therefore built strategic collaborations through the BEACON Biorefining Centre of Excellence (led by AU), the EPSRC Supergen Bioenergy Hub (AU leads the Feedstocks Topic) and the BBSRC Networks in Industrial Biotechnology and Bioenergy. We are also working with partners in two EU Bio-based Industries projects (GRACE and VAMOS) to link our research to downstream value chains. Our approach is to increase the diversity of products made from plants including for high-value compounds (Adams, Shah), and fermentation to fuels and chemical building blocks (Bryant, Winters, Gallagher).

Interconnected animal & human health. AU has a long and distinguished history of parasitology research (established in 1930) and is today a valuable national resource for expertise in the field. The opening of Wales' first Veterinary School at AU in collaboration with the Royal Veterinary College (RVC), along with the Sêr Cymru Centre of Excellence for Bovine TB creates the environment and impetus to expand research into important diseases of animals and man. IBERS research aims to understand the pathobiology of infection to underpin the development of diagnostic tests, vaccines and pharmaceutical interventions. It adopts a One Health approach to understand the epidemiology of diseases, including the social and psychological factors influencing human behaviour to improve the health, productivity and well-being of animals, and health and well-being of man. This strategy aligns with major infrastructure investments by AU, Welsh Government and the European Union in the Aberystwyth School of Veterinary Science, VetHub, the Sêr Cymru Veterinary Research Laboratories, the Centre for Innovation and Excellence in Livestock (CIEL) small ruminant unit, equine facility, biological service unit, the University farms and the Pwllpeiran upland research platform. IBERS research addresses parasite/vector biology (Pachebat, Hamilton, Santer); helminth diagnostics and control (Brophy, Chalmers, Hoffmann, Jones R, Morphew and as part of the Flatworm functional genomics initiative); bovine TB detection, protection and control (Abernethy, Gibson, Hewinson, Mur, Villarreal-Ramos, Vordermeier); equine health (Morrel, Nash); epidemiology and disease evolution (Abernethy, Hewinson, Risley, Williams H); and animal cognition markers of human neurodegenerative disease, and cognitive enrichment in farm and captive animal species (McBride).

Exploring & conserving biodiversity. IBERS biodiversity research addresses conservation and management of natural resources (Dennis, de Vere), stabilisation and remediation of ecosystems (Gwynn-Jones, Jensen, Scullion), and the ecology and evolution of populations and species in terrestrial (Beatty, Dennis, Griffith, Provan, Santer, de Vere, Whitworth), freshwater (Dalesman, McKeown) and marine (Ironsides, Shaw, Wilcockson) ecosystems. Our research spans evolutionary responses of species to changing environments (Beatty, Provan, Shaw); pollinator services (de Vere, Watson); organismal responses to pollution and the control of insect vectors (Dalesman, Santer); invasive species (Chen, Ironsides, Gwynn-Jones); sustainability of marine environments (Ironsides, McKeown, Shaw); and microbial communities of natural grasslands (Griffith), extreme (Rao), and rapidly changing (Edwards, Gwynn-Jones Wilcockson) environments, as well as the role of predatory myxobacteria (Whitworth). Sustaining natural

biodiversity in the face of interactions between wild and managed habitats and species is key, and a strategic target for our underpinning biodiversity research. IBERS works with local stakeholders around the Irish Sea to ameliorate the impacts of climate change through ecoengineering of coastal structures and offshore energy platforms (Ironsides, Shaw, Wilcockson) whilst future-proofing the utilisation of blue resources (Ironsides, McKeown, Shaw). The development of genomic resources for use in biodiversity conservation is an important area of our research, including DNA barcoding of UK flowering plants (de Vere), fungi (Griffith) and marine communities (Ironsides), along with molecular markers for species, habitat and ecosystem conservation and management (Beatty, McKeown, Provan, Shaw).

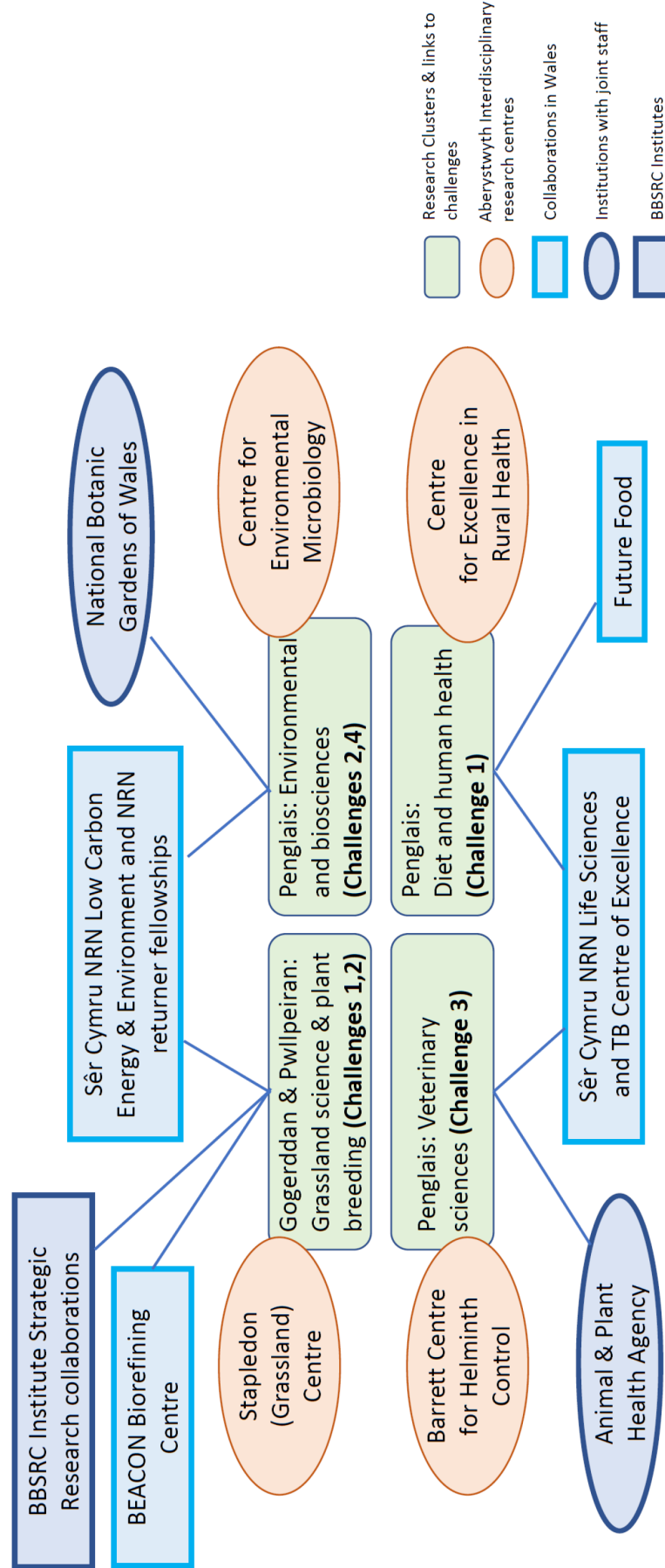
### **Structure**

IBERS is a large department, with research-only and teaching-and-research staff, located in multiple buildings on two campuses (Penglais and Gogerddan) and at an upland experimental platform (Pwllpeiran). At the REF 2014 submission, IBERS comprised three Themes. Since then the themes have been replaced by a departmental sub-structure of research clusters, which are responsible for line management of staff, operation of facilities and use of buildings, to reflect changes including the incorporation of sports and exercise science and the formation of a new veterinary sciences cluster. Researchers in each cluster are associated with facilities most relevant to their immediate research area. The four Research Challenges and associated challenge based research groupings (Table 1) therefore act as the principle mechanism for developing and building collaborations within IBERS. To identify and develop new **interdisciplinary topics of research** within AU, IBERS hosts workshops with other departments. Areas of mutual interest can lead to formal collaboration, and joint research applications, such as through the University supported Interdisciplinary Research Centres including the Barrett Centre for Helminth Control, the Stapledon Centre (for Grassland Agriculture), the Interdisciplinary Centre for Environmental Microbiology, and the Centre for Excellence in Rural Health Research. These and our expertise on the Research Challenges also extend to other research groupings in Wales for example as funded through the Sêr Cymru programme and the ERDF, in addition to large UK and international collaborations funded by UKRI and others (Figure 1).

IBERS engages with University wide mechanisms such as publisher deals for enabling **open access** publication, e.g., with JISC agreements and funds for UKRI-funded research for 'gold', and Aberystwyth Research Portal for 'green' open access publishing. In addition, IBERS has received a £175K grant from BBSRC (2017-22) associated with the Core Strategic Programme in Resilient Crops for making its outputs (approximately 50 per year) open access. IBERS makes software and raw-data sets such as from The National Plant Phenomics Centre open source so they can be "reused" by non-collaborating groups (i.e., independent use and publishing).



Figure 1: IBERS Structure, including how the four research challenges (summarised in Table 1) map onto the four organisational clusters (green boxes), and link to University Interdisciplinary Research Centres (orange ovals), Welsh Sêr Cymru National Research Networks (NRN) and ERDF collaborations (light blue boxes), external Institutions with which we have joint staff (dark blue ovals) and BBSRC Institutes where we have long-term strategic links including as part of our Core Strategic Programme (dark blue box).



IBERS engages with the support, guidance and training for researchers, provided by the University, so research is conducted according to appropriate **ethical, legal and professional frameworks, obligations and standards**. IBERS adheres to, and supports, the intention of the Animals (Scientific Procedures) Act 1986, as modified by EU Directive 2010/63/EU, and we are signatories to the Concordat for Openness in Animal Research. Each research project involving animals, whether covered by the Animals (Scientific Procedures) Act 1986 or not, is subject to an ethical review process by the Animal Welfare and Ethical Review Body which includes lay members, external members and representatives from across the University. Research involving human participation typically involves dietary intervention studies that may be linked to exercise routine or lifestyle/ health awareness. Such research protocols undergo assessment by the University Research Ethics Panel or NHS ethical review depending on the degree of intervention. Containment level 2 work involving plant and microbial genetic modification and genome editing experiments (e.g., CRISPR) receive assessment from the University Biological Safety/Genetic Modification committees and comply with HSE guidance on contained use. Procedures for containment level 3 activity are currently being developed as VetHub becomes operational. IBERS has adopted the EU implementation of the Nagoya (UN) Protocol, Regulation No. 511/2014 which builds on the Convention on Biological Diversity. IBERS pioneered implementation of these treaties and helped Defra when putting into legislation. IBERS has also recently obtained Home Office licences for both the growing and processing of hemp for pharmaceutical and industrial fibre applications, which has involved the establishment of additional processes and procedures to undertake this research.

### ***Impact strategy***

Our strategy for realising impact involves identifying and engaging with key stakeholders and the building of long-term strategic partnerships with industry to ensure our research reaches the market and is adopted by practitioners. In **plant breeding** our relationships with commercial partners ensures that our plant biology and breeding research is translated into new plant varieties with 37 varieties currently on the Agriculture and Horticulture Development Board (AHDB) recommended lists. The breeding of highly persistent forage clover varieties is one of our impact case studies. We have developed relationships and work with **supply chain actors** for red meat and dairy products, oat millers and biomass end users to identify research gaps and targets. Our engagement with farming unions (National Farmers' Union (NFU) and Farmers' Union of Wales (FUW)), and farmers and growers directly through events such as Cereals, Grasslands & Muck, Energy Now and the Royal Welsh Agricultural Shows ensures our research is relevant to sectorial needs. Our strategy involves **participatory on-farm research**, and in the PROSOIL+ project the participatory team supports six regional farmer groups in Wales to create a network to develop innovative soil practices and technologies. Removing the reliance on imported protein feeds within the ruminant supply chain is a case study. Engagement with the wider grassland community is achieved through the Knowledge Exchange Hub of Farming Connect (based at IBERS, and the principle agricultural extension mechanism in Wales), PreciseAg (HEFCW funded precision livestock team) and the British Grassland Society. We are adopting the same strategy on the bioeconomy, e.g., in the **BEACON Biorefining Centre** we carry out collaborative R&D with industry on biorefining, bioprocessing and the circular economy. In addition, we engage with policymakers and industry to identify research needs and also advise on routes to net zero, which is a case study. In the **Future Foods** project academics and industry undertake collaborative research into product development and assessment that would not be possible for SMEs on their own. IBERS researchers involved in this project have also developed a platform for the assessment of eating behaviour using urine biomarkers which is the subject of a case study. Our approach to impact also includes working with conservation bodies and policymakers on the **protection of habitats and landscapes** particularly in uplands, and also on the protection of species and an example on fungi is a case study. Our strategy for delivering impact also extends to the marine environment through both the **protection of coastal regions and their communities**, and also of ensuring the sustainability of fisheries in UK and international waters. Examples of both are included in our case studies.

Our **distance learning programme** for industry professionals (BioInnovation, AFTP) enables us to assist those working in agricultural and related sectors to keep up to date and learn new skills

including through the communication of IBERS research findings. To translate the latest scientific developments in bovine TB control and to share best practice we have established, with the Wales Veterinary Science Centre (WVSC), an annual 'AberTB' Conference which brings together veterinary practitioners, farmers, Animal and Plant Health Agency (APHA), Government, academia and other stakeholders. The conference provides continuing professional development (CPD) to vets and is seen as an important contribution to TB eradication in Wales. IBERS researchers also provide teaching to support the Vets Cymru annual conference at AU which is a two-day CPD event for vets and nurses working in small and large animal practice organised by the WVSC and the British Small Animal Veterinary Association.

### ***Priorities for the next REF Period***

In the next REF assessment period, IBERS will undertake research and innovation which addresses some of the most significant challenges of the 21<sup>st</sup> century spanning sustainable agriculture and food, climate change, one health, and biodiversity loss. Our future priorities are to enable:

- Agriculture to become more sustainable through greater cropping diversity, integrated soil management, improvement of nutrient utilisation, and less reliance on imported protein and inorganic fertilisers.
- Agriculture to become net zero by 2040, by building on our expertise to reduce greenhouse gas emissions from livestock, and to increase the greenhouse gas removal potential of biomass crops.
- A closing of the agricultural productivity gap through improvements in crop yield and yield stability, in animal health and nutrition, and in the instrumentation of agricultural and environmental systems with associated data management.
- The development of tools, e.g. genomic prediction, to accelerate plant breeding research into new crop varieties for food, feed, fuel and fibre.
- Greater understanding of the relationship between productivity and the delivery of ecosystem services on land and in the sea.
- Delivery of the Eatwell Guide, through work on crop nutritional quality and human diet.
- Development of diagnostic tests, vaccines and pharmaceutical interventions to control important diseases of animals and man.
- Improvements in animal and human health through a One Health approach to address zoonotic infectious diseases, parasites and antimicrobial resistance.
- The bioeconomy including the development of grass based biorefineries and co-development of food and non-food products.

## **2. People**

In the REF 2021 assessment period we have:

- Strengthened the vitality of IBERS by attracting world-class researchers including through the Sêr Cymru and Future Leader Schemes, and by significantly increasing the number of PhD students.
- Enhanced the sustainability of IBERS by attracting research fellows, and developing staff through mentoring and training programmes.



- Promoted inclusivity through policies on equality and diversity, modification of practices to facilitate inclusive participation, and targeted mentoring.

### **Staffing strategy**

IBERS staffing strategy recognises the priorities established within our four research challenges. A key strategic aim from REF 2014 was the establishment of an Upland Research Platform at Pwllpeiran. The appointment of a Chair (Wilkinson) and Reader (Fraser) in Upland Science has facilitated new research into managing these important ecosystems. To strengthen our biodiversity and conservation expertise we have made appointments of a Reader (Provan) and Lecturer (Beatty), and as part of our distance learning provision we have strengthened our livestock and agri-tech expertise by appointing Williams C and Wotton-Beard as lecturers. To strengthen our translational crop science, we have appointed a Professor in New Breeding Technologies (Jones H). In recognition of our longstanding relationship with Germinal, we will be appointing a Chair in Forage Plant Breeding, with a remit for the translation of IBERS plant breeding science into future forage varieties. A future priority aligned to this investment is to develop our underpinning plant breeding science by building on our expertise in genomic prediction and genome wide association studies, and to attract and recruit new staff into this area. Two other areas recently identified as future gaps where PhD students have been recruited in collaboration with Coleg Cymraeg Cenedlaethol, are soil science and precision livestock technologies for disease detection. IBERS is committed to advertise lecturer grade posts to cover these topics in 2024 when the studentships finish.

With the creation of the Aberystwyth School of Veterinary Science, we have appointed Abernathy as Chair and Head of School, building on IBERS' strength in animal science and parasitology. In addition, through the establishment of the Sêr Cymru Centre of Excellence for Bovine TB we have recruited a Chair and Head of Centre (Hewinson), a professorial position in veterinary immunology (Villarreal-Ramos 80%, Vordermeier 20%), a lecturer (Gibson), as well as postdoctoral and technical posts, with a senior lecturer under recruitment. These appointments have been made alongside capital investments in Aberystwyth School of Veterinary Science, VetHub, Sêr Cymru Veterinary Research Laboratories, and the CIEL small ruminant facility. A senior appointment (Hoffmann) has been made to direct VetHub for developing relationships with industry, government and the academic community. The senior leads of the Sêr Cymru Centre of Excellence for Bovine TB and Veterinary Research Laboratories and VetHub will be instrumental in enabling researchers and commercial partners to access state-of-the-art facilities for animal and public health research. A new Professorial position in Animal Science and Director of Farms (Moorby) was also created in 2018 to enhance the research capacity on, and use of, the University farms for research. IBERS encourages and supports fellowship applications from both internal and external researchers and has been successful in attracting new talent through Sêr Cymru, Marie-Curie and Future Leader schemes.

### **Staff development**

IBERS is committed to the implementation, and the spirit, of the Concordat for Researcher Development. This is particularly important in a department that includes research only as well as teaching and research staff. Our strategy is to support those in post, make succession plans for those with key skills, and invest in the research environment, including facilities, to enable research careers to flourish. It is recognised that within grassland science and plant breeding the current demographic profile mean we need to implement a succession plan and this is currently underway through attracting both a fellow (Lloyd) and the new Germinal Chair in Forage Plant Breeding (recruitment underway). Early career researchers and new lecturing staff are appointed mentors. Mentors and IBERS senior management (Head of Department, Director of Learning & Teaching, Director of Research, Theme Leader, Director of Knowledge Exchange & Commercialisation) set probation targets and identify mentors to help staff achieve these. Staff have an annual review meeting with their line manager (Effective Contribution Scheme) to discuss career aspirations and to set research and impact objectives appropriate for career stage, the extent of teaching duties, and other considerations. Promotions, through the University scheme also involve mentorship of the applicant.

Research staff are encouraged to attend external courses and workshops to learn or update skills. Recent examples where IBERS researchers attended courses include advanced microscopy techniques for plant-microbe interactions (Austria), Nanopore sequencing and data analysis (Oxford), drone training and pilot's licence (Aberystwyth), CRISPR/Cas-mediated genome editing and plant transformation (JIC), statistical and environmental characterisation at EPPN2020 (Wageningen), CyVerseUK RNAseq workshop (Earlham), compositionally appropriate analysis of omic datasets and CerealsDB workshop (Bristol). The computational/maths/statistics of biology, including for crop modelling and genomic prediction, is a fast-moving field. Experienced IBERS staff also develop their skills profiles through a combination of advanced literature awareness and online learning. IBERS researchers also train others, by teaching on internal and external technical courses (e.g. on phenomics and biorefining) and by hosting visiting researchers from the UK and internationally.

Training for transitions to greater independence for early career researchers enables staff to gain skills as well as extending personal networks. Training also provides opportunities for all our staff to learn to work across boundaries and cultures to become more effective 21st century leaders. Recent examples being the Academi Wales Summer School 'The Leadership Challenge – from efficient to exemplary' and the Welsh Crucible, both prestigious competitive schemes for personal and professional development of future research leaders in Wales. IBERS has two Research Development Officers (RDOs) who assist researchers in highlighting research opportunities, identifying other researchers to collaborate with across the University, and navigating the application process. The complexity of some application procedures and funder requirements means that the RDOs provide invaluable support allowing researchers to focus on the science. This support is particularly important for early career researchers including those applying for fellowships. The University's Department of Research, Business & Innovation also run workshops, often aided by IBERS staff, to help with grant building and research application processes. IBERS operates an internal peer support system in the preparation and submission of grants. This provides a mechanism to both support staff and for quality assurance/demand management. IBERS supports the development of an entrepreneurial culture and engages with AberInnovation on the Gogerddan Campus and also with BBSRC through the national productivity investment fund (NPIF) to enable innovation training for researchers, with the BioAccelerate scheme providing funding to assist both staff and students to bring their innovative ideas to fruition. Research staff involved in PhD supervision and examination also attend mandatory training through the Aberystwyth Graduate School before first taking on these responsibilities and attend refresher courses thereafter.

### **Research students**

The total number of IBERS research doctoral degrees awarded was 143.5 in the REF 2021 period. On a per annum basis, this represents an average of 20.5 PhDs awarded in the REF 2021 period compared to 11.4 in the REF 2014 period. This annualised increase, of 80%, represents the achievement of a key objective to grow postgraduate student numbers. External sponsorship of PhD students has come from research councils (BBSRC CASE, NERC, EPSRC), Welsh Government (KESS, Sêr Cymru), AHDB, European Union, TEAGASC Walsh scholarships, Coleg Cymraeg Cenedlaethol, and Industry. Success rates (i.e., submission within four years and passed) of the PhD students completing in the assessment period was 78%. This increases to 90% successfully completing after extensions for ill health and temporary withdrawals were taken into account. This demonstrates both our commitment to high quality PhD supervision and to providing support when needed. Notable recent developments in PhD studentship funding have been IBERS participation in 1) the BBSRC FoodBioSystems DTP partnership with Reading, Cranfield, Surrey, Brunel and QUB offering five cohorts of 4-year studentships, with the first cohort starting in autumn 2020; and 2) the UKRI Food Systems CDT with Greenwich, UCL, City, RVC, Brunel, Sussex, NIAB-EMR and Rothamsted offering three cohorts of 4-year studentships, with the first cohort starting in autumn 2021. The current PhD cohort in IBERS is 125 so we fully expect to sustain our increased postgraduate student numbers.

IBERS PhD students receive formal training, e.g., in writing, presentation, experimental design, and data analysis skills. In addition, they receive training in laboratory, field and bioinformatic skills. General information about expectations, responsibilities and opportunities are contained in the Faculty Postgraduate Handbook which is updated annually. Students are monitored by supervisory staff in formal regular meetings, which are documented and signed. Additional annual monitoring by the Aberystwyth Graduate School ensures oversight of student progress and allows students that are falling behind to receive assistance. The BBSRC DTP and UKRI CDT students receive additional training, attend summer schools and have opportunities for placements. Some of these opportunities are also extended to other IBERS postgraduate students where spaces allow. IBERS also encourages bioeconomy students to participate in the Supergen SHARE network which provides an informal but professional network of peers (PhD students, postdoctoral researchers and research fellows) with workshops and seminars to support knowledge exchange, promote mobility of early career researchers and interdisciplinary collaboration. Students are also encouraged to participate in UKRI YES programmes and in public engagement activities such as at the Royal Welsh show and during science week. Examples, of activities students have actively engaged in include: “plastics from plants”, “DNA isolation”, “Plants in Space” and “Biofuels, Bacteria and Bottles of Goo”.

### ***Equality, diversity and inclusion***

IBERS supports equality and diversity. In the current submission of 88 researchers, 32% are women and 68% men. This compares to figures of 23% women and 77% men from the 77 IBERS researchers submitted to UoA 6 and UoA 7 in REF 2014, and 19% and 81% respectively in RAE 2008. Over the period 2014-2020 we also achieved objectives of increased female representation at higher grades from zero to seven (Professors Hamilton and Kingston-Smith; Readers Davey H, Fraser, Howarth, Marley, Moore) and gender balance on our Departmental Executive team (four male, three female) compared with the position in REF 2014 (six male, one female). The three Faculty (Earth & Life Sciences) Associate Deans for Teaching & Learning, Research & Innovation and the Welsh Language are all from IBERS, and two are women (Hamilton and Kingston-Smith). Nevertheless, we acknowledge gender inequality still remains in our senior staff. We aim to remedy this through encouraging further participation in schemes such as Advance HE Aurora where six staff attended in the REF 2021 period. All recruitment is undertaken in accordance with well-established policies and procedures using an online, anonymised candidate application process. All interview panel members have to successfully complete an e-learning equality and diversity training module, and all appointment panels are gender diverse. AU supports all staff with caring responsibilities, there is an onsite nursery on the Gogerddan campus and practices, e.g. the scheduling of meeting times, are modified to facilitate inclusive participation.

IBERS currently has staff acting as mentees and mentors on the University's female academic mentoring programme. Staff members from the Department are also involved in the Women in Research Network, which has led to female staff members being able to feed into executive level decision-making and strategy planning. We have two nominated Equality Champions (Adams, Shah) who represent IBERS within the Equalities Champion Network; with the Faculty PVC the strategic lead on equality feeding directly into the University Executive. Champions channel issues from IBERS into the meetings, such as requesting University acknowledgement and support for staff during the 2020 lockdown, especially for those who are single parents with young children. A second role is dissemination and promotion of events and schemes running across the University, from LGBTQ+ film nights at the Art Centre on campus to the Red box scheme, providing free sanitary products to help alleviate period poverty. The Department has worked with the Diversity and Inclusion Manager on International Women's Day initiatives, initiatives for Black History Month, and helped to write the institutional Athena SWAN award submission. A member of IBERS staff (Yadav) coordinated the staff BAME Network from 2018-2020, working with the Diversity and Inclusion Manager to give an equal voice to BAME members of staff at the University.

The Sêr Cymru Low Carbon Energy & Environment National Research Network provided a Returning Fellowship Scheme designed to facilitate researchers returning to work from leave for

reasons of maternity, paternity, adoption, health or caring. The four IBERS researchers who received this support (Adams, Jensen, Farrar, Risley) are all part of our REF 2021 submission. IBERS researchers also receive training on unconscious bias, and in projects such as Supergen, where research funds are distributed, e.g., for fellowships, double-blind reviewing is used. The IBERS PDRA on the Supergen project was also selected for an event at Westminster for increasing BAME researchers' impact and engagement. In the BBSRC DTP FoodBioSystems project partners including IBERS take on additional responsibility to engage with other universities and institutions to increase awareness of PhD opportunities for students from less traditional backgrounds. The Food Systems CDT also strongly encourages individuals who have had career breaks (e.g., caring responsibilities, work in relevant sectors, or a change in disciplines or career paths) to apply for the advertised PhDs.

Principles of equality and inclusion have been incorporated into the REF 2021 selection process, as outlined in the University's Code of Practice. The Departmental REF Reading Committee has also included an independent member from a cognate department in the Faculty to monitor fair practice. Applications for output reductions for Individual Staff Circumstances were assessed through an anonymous process, with decisions made outside of the Department.

It is recognised that COVID-19 has had an impact on staff research, and for some staff, e.g., those with caring responsibilities, this impact has been significant. With the University, IBERS proposes to put in place a research recovery plan for at least two years to enable staff to take short blocks (1-2 months) of research leave, over and above existing opportunities. If successful we will build on the programme to assist more staff to have more space in the year to focus on their research, e.g., for networking, visiting another research group or industrial partner, writing grants or papers.

### 3. Income, infrastructure and facilities

In the REF 2021 assessment period we have:

- Demonstrated the vitality of IBERS by securing over £98.8M in research funding.
- Enhanced the sustainability of IBERS by developing new and upgrading existing world-class facilities.
- Strengthened inclusivity in IBERS research through training and mentoring to expand the number of research leaders, with one third of researchers winning grants of at least £400K during the REF 2021 period.

#### **Income**

The IBERS research income for the REF 2021 period was £98.8M. On a per annum basis, this amounts to £14.1M and represents an increase from £12.8M pa in the REF 2014 period. A comparison of the main income categories with those in the REF 2014 period is shown in Table 2.



Table 2: IBERS major research income categories, amounts and percentage of total research income. Comparison of REF2014 and REF2021 financial periods.

Funding Type	2008/9-2012/13 (5 years)			2013/14-2019/20 (7 years)		
	Amount (total)	Amount (annual)	Percentage (of total)	Amount (total)	Amount (annual)	Percentage (of total)
<b>BIS, Research Councils</b>	£31.8M	£6.4M	50%	£48.5M	£6.9M	49%
<b>UK Charities</b>	£1.2M	£0.2M	2%	£1.6M	£0.2M	3%
<b>UK Government</b>	£15.9M	£3.2M	25%	£17.6M	£2.5M	18%
<b>UK Industry</b>	£6.7M	£1.3M	10%	£9.9M	£1.4M	10%
<b>EU Government bodies</b>	£6.6M	£1.3M	10%	£18.3M	£2.6M	18%
<b>Other</b>	£1.9M	£0.4M	3%	£1.8M	£0.3M	2%

IBERS attracts strategic research funding from BBSRC, and most recently for the Core Strategic Programme in Resilient Crops (2017-2022, £8.6M) and the National Capability in Plant Phenomics (2017-2019, £600K). The BBSRC strategic programme income has declined within the REF 2021 period, but overall UKRI income has still increased. IBERS researchers have therefore had significant success in winning other sources of UKRI funding including: £15.8M (of non-strategic programme funding) from BBSRC, £4.5M from Innovate UK, £3.3M from NERC and £1M from EPSRC. Notably, IBERS research addresses challenges that span disciplines and feature as priorities in the Delivery Plans (2019) of four UKRI research councils; the current success rate with BBSRC is 31% (as reported in September 2020); and since 2014, 22 researchers won grants of £500K or more, and a further seven won grants of £400K or more.

Collaboration in Wales, previously structured into the funding of alliances such as BEAA, has been preserved through Sêr Cymru National Research Network projects. The Sêr Cymru scheme enabled IBERS to attract internationally leading researchers such as Hewinson to create and lead the Centre of Excellence for Bovine TB, and Lloyd who joined us in 2018, and was awarded a UKRI Future Leaders Fellowship in 2020. WEFO has supported significant translational research and industry engagement including for BEACON (£3.8M), Future Foods (£3M), VetHub (£3M), the Centre of Excellence for Bovine TB (£3M), Veterinary Research Laboratories (£2M) and BioInnovation (£1.2M). IBERS has participated in 12 Horizon 2020 projects (total value £3.5M), including the GRACE project for industrial crops on marginal lands (£939K), and in eight Interreg projects including on the effects of climate change on bird habitat (£823K), Climate Change adaptation through ecologically sensitive coastal infrastructure (£746K), and adaptation to climate change in aquaculture and fisheries (£633K). We also received funding from Welsh Government for the Farm Business Survey (£3.2M,) and the Farming Connect Knowledge Hub (£806K). IBERS also collaborates on global challenges with partners in LMIC countries through GCRF (three awards, £1.4M), Newton (19 awards, £1.2M awarded), and H2020 (two awards, £344K).

**IBERS infrastructure and facilities**, along with the associated technical expertise, enables us to address the four societal challenges which underpin our research strategy. **Research farms** at Gogerddan, Morfa Mawr, Trawsgoed and Pwllpeiran provide a unique platform extending over 1,000 ha, from 0-600 metres above sea level. What makes this stand out as a capability in the UK and Europe is the range of land types we have, and the range of altitudes, all within a 20 mile radius of the main laboratories, that allow us to work with crops and animals on extensive land areas and to do associated detailed measurements (with indoor housing and lab work). To capitalise on this resource in 2017 we established an altitudinal challenge gradient on four sites on Gogerddan and Trawsgoed farms at 70, 140, 250 and 340 metres above sea level. These sites exploit the geography of West Wales to provide a spectrum of environmental challenges



(including grazing) that are broadly representative of the growing conditions of approximately 80% of UK grasslands. The sites were instrumented, planted with diverse germplasm, and the resulting datasets integrated with those from controlled environment experiments to gain biological understanding of persistence, resilience and performance. This platform has enabled IBERS to participate in the ESFRI EMPHASIS project, a pan European network of climatically diverse research facilities, to enable predictive breeding and research into future climates. In addition, the plots are used in the BBSRC Strategic Programme in Resilient Crops, the H2020 GRACE project, and data is being used to model biomass productivity in the EPSRC Supergen Bioenergy Hub.

In 2020, IBERS expanded upland research capability by taking on the lease for 190 ha of additional contiguous land from Welsh Government at **Pwllpeiran** following its purchase from Defra. This builds on the earlier £2.4M investment from BBSRC to develop Pwllpeiran as an upland research platform. Pwllpeiran has a long history of involvement in upland grassland research, and in the late eighteenth century was host to the radical agricultural experiments undertaken by Thomas Johnes of the Hafod Estate. In the early twentieth century it then became the centre of George Stapledon's pioneering Cahn Hill Improvement Scheme. Pwllpeiran now provides a grassland continuum from relatively good quality reseeded pasture, through permanent pasture and semi-natural rough grazing, to heathland and blanket bog. A Calan Gate electronic feeding system for small ruminants (the only such facility in the UK) houses up to 48 sheep and 4 methane measurement chambers. Pwllpeiran as an upland facility is unique in England and Wales and is crucial to ensuring a robust evidence base for policy at a time of unprecedented political, economic and environmental change.

IBERS runs the **National Plant Phenomics Centre (NPPC)**, an automated system for non-invasive longitudinal phenotyping that can measure 1000's of plants in parallel. The NPPC, unique in the UK and one of a small number of networked facilities worldwide, allows populations of crops, and other plants, to be assessed by non-invasive sensors to record shoot growth and development, water content, photosynthetic activity, temperature and root development (using transparent soil columns). More detailed measurements of photo-physiology can be made on up to 2,000 plants on our small plant platform. The NPPC is a core member of international consortia (e.g., EPPN, EMPHASIS) that aim to deliver phenotyping of crop and model plants. The NPPC also has bilateral links with phenotyping centres in Denmark, France and Canada. Extensive glasshouse and controlled environment facilities are also available including the Venlo (26 compartments offering control of temperature and day length), and 10 Sanyo and Saxil cabinets/rooms which provide control of day length, temperature and humidity. IBERS crop experiments are also carried out in a custom Soil-Plant-Atmosphere Facility (instrumented rain-out/ lysimeter), which acts as a half-way house between the field and glasshouse.

The IBERS **Seed Biobank** comprises a collection of over 35,000 accessions of global importance for forage grasses, forage legumes, and energy grasses. For a number of species the facility holds the largest ex situ collection worldwide, and for many accessions acts as an irreplaceable resource where original agricultural or natural collection sites no longer exist. IBERS specialises in the collection and curation of grass and legume species held in medium (20-50 years) and long term (50-100 years) storage under controlled environmental conditions. Long term security of this unique resource was ensured by a £6M investment as part of the AberInnovation development. Our associated quarantine glasshouses were refurbished in 2016 and are one of few facilities in the UK that can import, multiply and store field collected plant material. IBERS also collates the European central crop databases for *Lolium* and *Trifolium*, and makes the annual submission for all UK held crop biodiversity to the European Genetic Resources catalogue (Euriscope) which is then harvested by Genesys-pgr, the global portal for genetic resources for the FAO. In addition, IBERS has an array of isolation glasshouses for the controlled crossing of plants for discovery science and plant breeding. In our purpose-built seed processing unit, within the AberInnovation development, seed samples can be prepared from research to precommercial (10 tonnes) scales in line with International Seed Testing Association standards.

**Animal facilities** enable dairy and beef cattle, sheep, goat, alpaca and broiler chicken research. Specialist facilities enable the measurement of individual animal feed intake and digestibility, and enteric methane emissions from housed and free-ranging livestock. A herd of 400 dairy cows at Trawsgoed Farm will be milked by newly acquired robotic units. The rumen function laboratories include the specialist “D-unit” that has facilities for preparation and maintenance of cannulated animals (under Home Office licencing) that are required for detailed in vivo assessments of forage digestion to complement in vitro studies using rumen simulation fermenters, and a collection of pure cultures of bacteria, protozoa and archaea. The equine facility has stabling for 60 horses with eight in a dedicated research block, and an exercise yard. A biological service unit for rodents contributes to research and impact outputs relating to drug discovery for human parasitic diseases (Schistosomiasis). In addition, IBERS hosts the CIEL small ruminant research platform (£1.4M, Innovate UK and AU). Our research into the marine environment and ecosystems is supported by aquaria capable of housing fresh or saltwater organisms, and research vessels (fully Maritime and Coastguard Agency coded) including a 6.5m rigid-inflatable boat and a purpose built 10m Cheetah catamaran that can carry up to 12 passengers and crew with associated oceanographic sampling and scientific diving equipment.

**VetHub** is a recent European Regional Development Fund (ERDF) and WEFO investment of £3M in containment level 2 and 3 facilities for veterinary research in Wales. This will allow academic-industry collaboration in animal health, zoonoses and veterinary diagnostics, and builds on existing parasitological strengths in IBERS as well as the establishment of the £3M ERDF and WEFO funded **Sêr Cymru Centre of Excellence for Bovine TB**. AU is also developing laboratories adjacent to VetHub for the Sêr Cymru team for research in immunology and molecular epidemiology through a further £2M ERDF and WEFO investment. These state-of-the-art facilities for veterinary research in Wales complement the establishment of the School of Veterinary Science. **Roboworm** is an automated platform enabling the repositioning of existing drugs or the identification of new compounds as next-generation anthelmintics. The platform has a capacity of 100,000 tests per annum and comprises an integrated tissue culture facility, automated compound distribution/washing workstation and high content image analysis system coupled to customised software for segregating drug-induced schistosome phenotypes. This unique system draws together the very latest advancements in instrumentation and dramatically transforms the speed at which new anthelmintics can be identified.

Significant investment in **imaging equipment** through HEFCW funding has allowed an upgrade to confocal and electron microscopy facilities, and enhanced FTIR capability for high throughput metabolomic phenotyping. **Genetic transformation laboratories** and associated glasshouse enable the manipulation of monocotyledonous model and crop plants, including through genome editing (CRISPR/Cas). The **Analytical Chemistry** unit at IBERS holds ISO/IEC 17025 accreditation in 19 techniques of forage and nutrient analyses and processes internal and external samples. The **DNA sequencing laboratory** represents a local capability for smaller projects especially where a faster turnaround is needed using Illumina MiSeq for SNP, metagenomics and amplicon sequencing. The **metabolomics facility** at IBERS include high resolution mass spectrometry and chromatography techniques (GC-MS-MS, GC-tof-MS, LC-MS) for untargeted metabolomics, chemical and structural analysis, proteomics and cell profiling.

The IBERS **High Performance Computer Cluster** (HPC) consists of 544 CPU cores and 4TB RAM spread across 13 computer nodes. There is 43TB storage capacity with an additional 11TB of fast access disk, which provides working space for over 100 users. The IBERS cloud (a collection of stand-alone high-performance computers dedicated to deploy 'on demand' servers and/or services) underpins the web-based services for bioinformatics (e.g., Galaxy) as well as other services. The IBERS cloud is composed of 55TB of dedicated storage, 104 cores and 1TB of memory RAM. There is also a 1.2Pb of disk space available for long-term storage connected both to the HPC and IBERS Cloud, with storage repositories backed-up on a weekly basis.

Research horizons have recently been expanded by the £40M investment in **AberInnovation**, a joint project between AU, BBSRC and Welsh Government created to convert the grand

challenges of food, climate change and clean energy into sustainable and prosperous opportunities for society. Facilities include state-of-the-art infrastructure for pilot scale biorefining, food processing and associated analytics. For biorefining, this includes a **Primary Processing facility** (100-1,000 kg/hour) for biomass milling, pelleting, drying and juicing. It also houses steam explosion equipment for pressurised hydrothermal pre-treatment of feedstocks. A food grade **Downstream Processing facility** includes pasteurisers, reactor vessels and membrane, centrifugation and spray drying capability (50-2,000 litres/hour). The **Pilot Fermentation Facility** provides food grade facilities at scales from 1-300 litres; and an automated system for assessing biogas potential of feedstocks. A **Clean Room** provides a high hygiene (ISO7) area for finishing (purifying/crystallising/drying) and bagging small scale products (mg to kg) in a controlled atmosphere environment. The **Industrial Biotechnology Suite** provides state-of-the-art (aerobic and anaerobic) microbial phenotyping and fermentation platforms to identify novel microbes and characterise the metabolism of new production strains developed using synthetic biology. The **Bioprospecting Suite** provides extraction of samples at a range of scales (mg to kg), fractionation of semi-purified natural products and liquors, accelerated solvent extraction of natural product components, and high-performance counter current chromatography for rapid liquid-liquid separations. **Food grade processing and laboratories** conform to BRC standards for meat; dairy and liquids, including pilot scale pasteurisation and filtration in batches (up to 1,000 litres) and continuous mode (5,000 litres/day); cheese, cultured milk products, butter and frozen product manufacturing (1-100 litre batches); and grains and pulses including on-site baking. A **Kitchen and Sensory Booths** enable trained taste panels and real-time evaluation of organoleptic and sensory properties of novel foods. The facility enables assessments of food composition, storage, shelf life and safety characteristics. The facility also integrates with the IBERS-based Well-being and Health Assessment Research Unit to help develop the evidence base for health claims relating to novel foods. For example, the facility provides chemical content analysis, comprehensive profiling and structural elucidation for analysis of metabolites in extracts using ultra high-resolution LC and GC mass spectrometry, Triple Quadrupole mass spectrometry for targeted quantification of secondary metabolites in complex mixtures, and UPLC and GC for analysis and quantification of sugars, organic acids and alcohols.

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

In the REF 2021 assessment period we have:

- Supported the vitality of IBERS by hosting international visitors, and conferences, and engaged with public, private and third sectors, to enhance social and economic wellbeing, and environmental sustainability.
- Consolidated the sustainability of IBERS by developing new collaborations both nationally and internationally.
- Strengthened inclusivity in research, by valuing staff contributions to wider society and the economy, and by practising co-production of research with stakeholders, and through access and benefit sharing.

##### **Collaboration**

IBERS researchers collaborate with partners in the UK and internationally. We previously received funding with Bangor University through BEAA and made a joint submission for REF 2014. That funding has come to an end but a strong legacy of the alliance remains in the number of joint papers published (65 papers in the REF 2021 period), and also in collaborative projects such as BEACON. The IBERS joint appointment, with the National Botanic Garden of Wales (de-Vere), brings important expertise on pollinator science and green infrastructure. The Welsh Government Sêr Cymru programme supported the establishment of the Centre of Excellence for Bovine TB. Through the centre, IBERS has two joint appointments with APHA (Villarreal-Ramos, Vordermeier), and two are members of the Jenner Institute (Hewinson, Vordermeier). IBERS also participated in the Sêr Cymru National Research Networks which enhanced collaboration across Welsh Universities. Under the topic of Low Carbon Energy and the Environment, IBERS was involved in projects on: Cleaner Cows, Climate Smart Grass, MultiLand, and Plants & Architecture, involving support for both PDRAs and PhD students. Under the Life Sciences topic, IBERS was involved in one PDRA project on the prospecting and

characterisation of novel antimicrobials from bovine metagenomes, three platform grants on the use of high-throughput robotics for anthelmintic screening and a further eight PhD studentships.

According to SciVal 86% of our research outputs involves external collaboration, with 61% of that collaboration international. For example, in the REF 2021 period, there were 23 UK and 16 international institutions with which we co-published at least 20 papers. In Europe, collaborations are supported through funding schemes including Horizon 2020, Interreg, EIT Health and Climate-KIC. IBERS is also an active member of the European Plant Science Organisation, Animal Task Force (via CIEL), and the Wales Higher Education Brussels group. Through these groups we network with European research institutions and policymakers on topics including grasslands, bioenergy, access and benefit sharing and GM technologies. IBERS researchers also use partnering awards to build international networks, and since REF 2014 have held UKRI partnering awards with Australia (Donnison), Brazil (Farrar), Canada (Langdon), China (Langdon), India (Gallagher), Taiwan (Huang), and through the British Council with India (Mur).

IBERS researchers work in international teams to develop enabling tools and resources for crop science and plant breeding. For example, during the REF 2021 period, this included genetic maps (*Miscanthus*), physical maps (*Lolium* and red clover) and genome sequences (*Lolium*, red clover, *Miscanthus* and oats). On forage and energy grass genomics we collaborate with the Earlham Institute, JGI and Aarhus University. On oats we are part of a consortium involving US, Canadian and European partners on the genomics of diploid *Avena* and hexaploid pan-genome assemblies. We also work with JIC on gene identification in target pathways and with partners in Turkey, Georgia, Morocco and Kazakhstan on diversity and adaptation in oats.

IBERS collaborates on forage crops with CGIAR centres CIAT and ILRI in the Forages for Africa partnership, and in the GROW and BRIDGE Colombia projects led by Earlham with CIAT on forages for highland and lowland South America. On grassland research we collaborate with Rothamsted (e.g. at North Wyke), and are expanding links with partners in the Andean region and Namibia on sustainable management of native grasslands/ rangelands. In a series of EU funded projects (e.g., most recently RE-DIRECT, THREE C) IBERS have collaborated, with Kassel University and others, to valorise biomass arising from conservation management as a resource for energy, biochar and green materials.

IBERS has collected *Miscanthus* species in South East Asia since 2006, and has ongoing collaborations with researchers in China (Nanjing Botanic Garden), Japan (Hokkaido University), Korea (Seoul University) and Taiwan (National Taiwan University and Endemic Species Research Institute). We have partnerships in Sicily (University of Catania) and Germany (Julius Kühn-Institut and Hohenheim University) on seed production and phenotypic analyses. A number of IBERS bred *Miscanthus* hybrids have been trialled in locations across Europe in a series of EU Framework projects (OptiMisc, Optima, Watbio, GRACE). IBERS collaborates with DOE Bioenergy Centres and partner organisations including at the University of Illinois on *Miscanthus* genomics and the Noble Research Institute on the mapping of energy crop traits. Bacterial endophytes have also been the subject of US and Brazil collaborations. In bioenergy we have collaborated through the EPSRC Supergen programme since 2003 and currently with Aston, Bath, Manchester, Imperial College, Southampton and UKCEH. We have also collaborated on the environmental impacts of biomass cropping through a series of projects (NERC CarboBioCrop, ETI ELUM, EPSRC MAGLUE) generating >30 papers since REF 2014 with Aberdeen, Southampton and UKCEH. Our collaborative trials from these projects represent a scarce scientific resource as few experiments on these crops have been measured for so long and characterised as intensively. Data from the trials, combined with those from European collaborations, are used to refine crop models (e.g., MISCANFOR) to generate the next iterations in yield and carbon sequestration modelling.

IBERS leads the Flatworm Functional Genomics Initiative (FUGI), a Wellcome Trust funded UK/EU/USA collaboration to develop a functional genomics toolbox for studying blood flukes and tapeworms, which cause significant human and animal diseases. We are part of a ZELS Consortium (ETHICOBOTS) on bovine TB that includes the Department of Veterinary Medicine,



University of Cambridge, APHA, The Institute of Global Prosperity, UCL, The National Animal Health Diagnostic and Investigation Centre Ethiopia, The Ethiopian Institute of Agricultural Research, The Armauer Hansen Research Institute, The Aklilu Lemma Institute of Pathobiology, and the Swiss Tropical and Public Health Institute.

### **Contribution to the research base**

IBERS researchers make significant contributions to the vitality and sustainability of the wider research base in agriculture, food and veterinary science through participation in subject conferences, organisations and journals.

IBERS staff are involved in the peer review and post award assessment of research grants nationally and internationally as **members of awards and review panels**. For example since 2014, IBERS researchers have been members of UKRI, Defra and Wellcome panels including Donnison (GCRF, Newton, BBSRC Bioscience for Industry Strategy Panel, UKRI Circular Economy SAG, EPSRC review college), Draper (MRC Nutrition Research Partnership, Wellcome Trust/WHO), Edwards (NERC Scientific Facilities Added Value Panel, NERC review college), Skøt (BBSRC Committee B), Gallagher (BBSRC Committee B, Industrial Case Studentships), Hegarty (BBSRC Committee C), Jones H (BBSRC Committee B), Kingston-Smith (BBSRC Committee B, UKRI Future Leaders Fellowships), Moorby (GCRF), Hewinson (Defra bovine TB), Hoffmann (Wellcome Trust), and Yadav (Newton, BBSRC Follow-on-Fund, UKRI AgriTech). IBERS researchers have also been involved in international panels including Donnison (ERA-CAPS); Gallagher (EU H2020 BBI); Howarth (Agriculture and Agri-Food Canada; EU PRIMA; Swedish Foundation for Strategic Research); Kingston-Smith (Department of Agriculture, Food and the Marine, Ireland); and Yadav (EU COST).

Through **editorial work**, IBERS staff have supported scientific publishing including as Editor in Chief of Parasitology International (Hoffman), Deputy Editor of the European Journal of Soil Science (Scullion), as Annals of Botany Company member (Donnison), and as members of editorial boards for 30 journals.

IBERS has **hosted conferences** in Aberystwyth including for the 25<sup>th</sup> European Grassland Federation Conference (2014), Oats 2020 Conference (2015), 12th British Grassland Society research Conference (2015), British Society for Parasitology (2018), AberTB Annual Conference on Bovine TB (2019), and British Meiosis Meeting (2019). In addition, IBERS researchers have regularly been on **international organising committees** and chair sessions at conferences and workshops in Asia, Europe, North America and Australasia. For example, this has included Molecular Breeding of Forage & Turf (2016, Lanzhou), International Oat Conference (St Petersburg 2016, Perth 2020), Biomarkers of Dietary Intake and Exposure (Washington, 2018), Gordon Research Conference on Chronobiology (Barcelona, 2018), Plant and Animal Genome Workshops on Grasslands and Bioenergy Grass Genomics (San Diego, annually 2014-20), PhenoDays (Berlin, 2016), and InterDrought (Hyderabad, 2017).

Staff in IBERS have also contributed to research leadership during the assessment period as **officers or committee members** of societies, including Beatty as Chair of a Special Interest Group in the British Ecological Society; Fraser as a Trustee of the British Grassland Society; Hamilton as Vice-President Elect of the British Society for Parasitology (2020); de Vere as Member of the Linnean Society Council; Moorby as President of the British Grassland Society; Nash as a Council Member and Chair of the Conference Organizing Committee for the British Society for Animal Science; Pachebat as Honorary Treasurer of the British Society for Parasitology; Villareal-Ramos as Chair of the Vaccine Affinity Group of the British Society of Immunology; and Whitworth as a Trustee and Council Member of the Microbiology Society. IBERS staff are also recognised through Fellowships including the the Learned Society of Wales (Doonan, Hewinson), Royal Society of Biology (Donnison, Farrar, Hamilton, Jones H, Whitworth), the Royal Entomological Society (Dennis), the Royal Society of Arts, Manufactures and Commerce (Donnison), the Royal Society for Tropical Medicine and Hygiene (Pachebat), the Royal Geographical Society (Edwards) and the British Association of Sport and Exercise Sciences (Thatcher). IBERS researchers also act as trustees or in an advisory role for a wide



range of organisations including for other universities, for research projects, industry and charities.

The impact of our research has been recognised through a number of **award nominations and successes**. In June 2015, IBERS won the NIAB Variety Cup for its AberGreen grass variety, making it the second forage variety ever to be recognised with the award. In March 2014 the BEACON Biorefining Centre, won the European Commission's RegioStars Sustainable Growth award, and in 2019 won a Sustainable Academy Award from Cynnal Cymru. In 2015, IBERS were finalists in PraxisUnico and RCUK impacts awards for the fair and equitable use of crop genetic resources. In 2016 IBERS was commended in the BBSRC Excellence with Impact competition, and in 2020 we became a finalist in the Green Gown Competition for our work on Miscanthus seed-based hybrids contributing to net zero targets. A number of our researchers have also been recognised, for example in 2017, Edwards was awarded the inaugural Royal Geographical Society Walters Kundert Arctic & Mountain Research Fellowship. Leading up to the 175th anniversary of the Royal Society of Chemistry in 2016, Shah was profiled as one of the 175 Faces of Chemistry. In 2020, Williams H won the Eilir Hedd Morgan Award in recognition of research excellence and contribution to Welsh medium higher education by an early career researcher.

### ***Contributions to the Economy and Society***

IBERS research culture includes a strong translational ethos leading to significant contributions to the economy, environment and society. In their 2014 report BiGGAR Economics identified that for each £1 of public funding invested in IBERS, it generated £12.18 of benefit to the UK economy. In addition, it was identified that IBERS makes a substantial local economic contribution, supports the competitiveness of the UK agri-food sector, improves food security both within the UK and overseas, generates benefits for human health in the UK and internationally, enables international development, helps to reduce the carbon emissions of agriculture in the UK, develops ways of adapting to and mitigating against climate change, and contributes to better public policy.

Our contribution to the economy includes commercial applications of our **plant breeding** with our varieties achieving significant market adoption. We have a >30-year relationship with Germinal Holdings which has resulted during the REF 2021 in the release of 11 new forage grass and clover varieties (see Table 3) and which typically represent approximately 30% of UK seed sales for these crops. IBERS also operates one of the three UK sites for the running of national list, recommended list, and descriptive list herbage trials for the British Society of Plant Breeders (BSPB). We also have a >30-year relationship with Senova on oats which has resulted in the release of 12 new oat varieties during the REF 2021 period (see Table 3), which typically represent 65% of UK seed sales for the crop. The Senova relationship has enabled the AU-led InnovOat, a BBSRC LINK project with partners at NIAB, Heriot Watt University, and the BOBMA research group, to use modern breeding technologies to capture and enhance the health benefits of oats in new varieties. Over the last 15 years IBERS has developed a plant breeding programme in Miscanthus with commercial partners Ceres (subsidiary of Land O' Lakes) and Terravesta, using novel germplasm collected in Asia. Currently the first six Miscanthus varieties are undergoing variety registration with the EU Community Plant Variety Office. Other breeding programmes include grain legumes (peas and field beans with Wherry, marketed by Senova with the first two varieties, which exhibit higher yield and enhanced protein, listed in 2020), reed canary grass, and hemp for pharmaceuticals and fibre.

**Table 3: List of the 25 IBERS bred varieties that were added to recommended lists (RL), national lists (NL) and descriptive lists (DL) during the REF2021 period. A further six Miscanthus varieties are currently undergoing variety registration.**

Variety name	Date added	List type	Crop type
AberImage	2020	NL	Hybrid Ryegrass (tetraploid)
AberTest	2020	NL	Late Perennial Ryegrass (diploid)
AberZeus	2016	RL	Intermediate Perennial Ryegrass (diploid)
AberSpey	2017	RL	Intermediate Perennial Ryegrass (tetraploid)
AberLee	2017	RL	Late Perennial Ryegrass (diploid)
AberBann	2018	RL	Late Perennial Ryegrass (diploid)
AberSwan	2018	RL	White clover
AberWolf	2014	RL	Intermediate Perennial Ryegrass (diploid)
AberLasting	2016	NL	Hybrid white clover
AberEdge	2016	NL	Hybrid ryegrass
AberRoot	2020	NL	Festulolium
Coracle	2015	NL	Winter husked oat
Maestro	2016	RL	Winter husked oat
Griffin	2017	RL	Winter husked oat
Penrose	2017	NL	Winter husked oat
Galloway	2018	NL	Winter husked oat
Puffin	2019	NL	Winter husked oat
Cromwell	2019	NL	Winter husked oat
Olwen	2020	NL	Winter husked oat
Peloton	2015	DL	Winter naked oat
Conway	2014	RL	Spring husked oat
Spurtle	2015	NL	Spring husked oat
Madison	2019	DL	Spring naked oat
Norton	2020	RL	Winter bean
Vincent	2020	RL	Winter bean

Regular stakeholder meetings, including as part of collaborative (e.g., LINK, IPA or Innovate UK) projects, ensures that **producers and end-users** are aware of our research and future research priorities are aligned to industry needs. In the Innovate UK funded Sustainable Forage Protein project we worked with Germinal and Bangor, and farmers from the Waitrose beef, lamb and dairy supply chains (Dovecote Park, Dalehead Foods, Coombe Farm, Müller). In oats we work with Senova along the supply chain including Oat Services (high value compounds); PepsiCo, Richardson, White's and Morning Foods (oat millers) and Camgrain (oat growers) through InnovOat (BBSRC-LINK) and OptiOat (Innovate UK) projects. Likewise, the PeaGen BBSRC-LINK project includes Dalehead Foods, Gressingham, Moy Park, Stonegate and the Processors and Growers Research Organisation. In the GIANT (BBSRC and Defra LINK) and MUST (BBSRC/Innovate UK) projects, IBERS worked with the biomass supply chain including with growers, NFU, Terravesta and module-based plug producers for the upscaling of Miscanthus seed-based hybrids, and end users Drax, Shell and Brigg.

Contributions to society include **participatory farmer and stakeholder engagement** through the PROSOILplus project (Marley, Scullion), funded by the European Agricultural Fund for Rural Development. In this project IBERS is working to help livestock farmers safeguard soils against the impacts of climate change and to optimise nutrient use efficiency. The Pwllpeiran

experimental platform has its own stakeholder group, the Pwllpeiran Associates, which includes policymakers and implementers from NFU, FUW, RSPB, National Trust, Natural Resources Wales (NRW), the British Grassland Society, and award-winning grassland farmers from the region. Pwllpeiran acts as a base for the Cambrian Mountains Initiative and two project officers working on developing a Parc Naturel designation for the area have an office on site. Open days on our own farms or on local farms with whom we collaborate, highlight new cropping options, systems and agronomies for practitioners, farming groups and the Young Farmers Association.

In the **BEACON Biorefining Centre** IBERS works with industry on collaborative R&D in biorefining, bioprocessing and the circular economy. The project is funded through ERDF by WEFO and recently celebrated its tenth anniversary at an event in which Wales First Minister, Mark Drakeford, spoke. BEACON has supported 76 enterprises to introduce new to the firm products/processes in collaborative R&D projects since it was refunded in 2015. Notable follow-on projects from such collaborations (e.g., with Innovate UK or Smart Cymru funding) include working with 1) Quorn and Waitrose on a ready meal product with reduced salt content but no adverse effect on taste, 2) Pennotec on adding value to crab shell waste by processing into high value product (chitin), and 3) Fiberight converting sugars derived from municipal solid waste to lactic acid for bioplastic production. BEACON is also one of the four members of BioPilotsUK, the alliance of open access biorefining centres (along with CPI, York BDM and IBioIC). IBERS with BioPilotsUK aims to de-risk the commercialisation of bio-based products and processes by trialling new technologies to ensure industrial partners are investing in the right technologies for their business.

Work by researchers in the **Sêr Cymru Centre of Excellence for Bovine TB** (Hewinson, Vordermeier) and their colleagues at the Animal and Plant Health Agency recently culminated in the granting of Animal Test Certificates for a bovine TB cattle vaccine (CattleBCG) and a companion DIVA skin test (DST-F) that distinguishes vaccinated from infected animals. The field trials will be conducted over the next four years on behalf of Defra, the Welsh and Scottish Governments. International collaborations funded through a ZELS initiative (ETHICOBOTS) and a DFID/Gates Foundation Grant (Accelerating Bovine TB Control in Developing Countries) are evaluating these tools in Ethiopia and India. In another initiative, an 'EpiHub' is being established where molecular biologists and epidemiologists from IBERS, APHA and Welsh Government come together to study the transmission of animal diseases and identify effective local and national interventions. Close working relationships between veterinary centres, veterinary delivery partners, farmers, APHA and Welsh Government will ensure that outcomes of IBERS research are translated into practice and policy. The IBERS One Health research grouping will bring researchers together to study antimicrobial resistance, health communication and for the control of zoonotic diseases. Activities undertaken within the Barrett Centre for Helminth Control, a University Interdisciplinary Research Centre established in 2015, have led to contract research and collaborative opportunities with industry (ELANCO Animal Health, MSD Animal Health, Bimeda Animal Health, Boehringer Ingelheim, Techion, Informatics Unlimited, Ridgeway Research, Bio-Check) on detecting and treating helminth infections of animals and humans. IBERS is one of few UK locations that maintain *Schistosoma mansoni* lifecycles and provide soluble egg antigen to the Health Services Laboratory in London for detecting schistosomiasis in patients referred to them by general practitioners across the UK. Three patents have been submitted in this census period on anti-infectives (Hoffmann) and diagnostics (Brophy, Morphew).

Additionally, IBERS contribute to public understanding of science through **public engagement and science communication**. This has included the designing and running of hands-on activities at the Royal Welsh Show (the largest agricultural show in Europe), National Eisteddfod, National Science Week, and the Royal Institution Christmas Lectures. The TrioSciCymru project (2017-2021) is a European Social Fund partnership between the Welsh Government and four universities (£1.2M to AU) that has provided targeted science interventions at Key Stage 3 and is encouraging students from under-represented groups to study science. We also participate and help host sessions at the Wales Real Food Festival (in Aberystwyth in 2019, online in 2020), and with international events such as Fascination of Plants Day. We engage with local

community groups such as gardening clubs and community gardens, and through the Well-being and Health Assessment Research Unit on diet and health, through public lectures and a Science Café series hosted at the Aberystwyth Arts Centre. IBERS works with other communicators such as Cows on Tour; artists, including Miranda Whall, on creating a sheep's eye view of the Cambrian Mountains and Tim Knowles, on visualising the environment; the Hay Literary Festival linking the farmed upland landscape to poetry; the National Botanic Garden of Wales on the "Power of Grasses" display boards and a "Plants in Space" activity, and with the Centre for Alternative Technology on the building of the world's first Miscanthus house. We communicate our research through the Science Media Centre, local and national media and in public debates, on topics such as sustainable agriculture, healthy diets, net zero, animal disease, and the role of GM.

Finally, IBERS makes important contributions to society by **engaging with policymakers** in Wales, UK and globally on topics including climate change, land use, uplands, bovine TB and sustainable fisheries. For example, expert advice has been provided to the Welsh Government and Welsh Chief Vet on bovine TB (Hewinson), to Welsh Government on Pandemic Influenza through the Environment Group (Edwards), to Defra on the mitigation of livestock greenhouse gas emissions (Moorby), on blue growth and the maritime environment (Ironsides, Moore), fisheries boundary policy in South Africa (Shaw), on grasslands to the European Commission (Donnison), on management of uplands to UK and Welsh Governments (Fraser), and on food and drink policy (Draper). Griffith has authored reports for Welsh Government, Natural England and Environmental consultancies on the conservation and protection of fungi. Hewinson was an author of the Review of England's Bovine TB Strategy, a report to the Secretary of State for Defra. Most of the recommendations from this report were accepted and formed the basis of Defra's five year strategy for TB eradication. Hewinson was also a member of the WHO consultation panel on zoonotic TB (Geneva 2016) which led to a comprehensive roadmap released in 2017. In addition, he was a Member of the Blakett Panel on wide-area Biological Detection, chair of Defra's Scientific Oversight Group for the design and implementation of cattle vaccine field trials (2015-2016) and member of five Defra Advisory and Review Groups on TB. Donnison co-authored a report for DfT on UK Biomass Availability Modelling (2020) and has been on advisory groups for the NFU on net zero and for the Committee on Climate Change Reports on Biomass (2018) and Land Use (2020). Jones, H, was involved in round table meetings with UK MPs and Defra Ministers, Michael Gove and George Eustice, to discuss future UK policy on biotechnology innovation and regulation.

IBERS has responded to multiple UK and Welsh Government consultations, hosted a visit from the UK Government Office of Science on the agricultural productivity gap and engaged with All-Party Parliamentary Groups on: i) Science and Technology in Agriculture, on Grassland science and innovation – the key to a Green Brexit; ii) Latin America with Earlham on the development of the GROW Colombia partnership and iii) Science & Technology in Agriculture during the progression of the Agriculture Bill and gene editing legislation. In the coming decade, there will be major and urgent areas of agriculture and food policy which will require policy input and IBERS is committed to engage with the relevant stakeholders in Wales, UK and internationally.