201

Annual Report

Genes to Energy | Energy to Yield

plant energy biology

ARC CENTRE OF EXCELLENCE


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The best people, cutting-edge resources and a stimulating environment leads to ground-breaking research.

The Centre

CENTRE OVERVIEW

The Australian Research Council Centre of Excellence in Plant Energy Biology (PEB) is focused on better understanding the way in which plants capture, convert and use energy in response to environmental change, with a view towards improved plant energy efficiency.

Vision

To enhance plant energy efficiency by simultaneously optimising energy capture, conversion and use in changing environments, in order to improve the sustainable productivity of plants.

Mission

- Define the complex system that determines overall energy efficiency in plants.
- Discover the key signals, 'gatekeeper' cells, and (epi)genetic controls that regulate this energy system.
- Manipulate these regulators in combination to optimise energy efficiency across the whole plant and enhance yield.

Strategic Priorities

- To elucidate the fundamental mechanisms of energy biology regulation in plants.
- To be a leading Centre for advanced training and education for plant and computational biologists, in Australia.
- To build strategic collaborations for Australia within the international science community.
- To enhance plant biotechnologies in order to build technological innovations and aid Australian agricultural innovation.

Tapping into the potential of plants is what drives research at the ARC Centre of Excellence in Plant Energy Biology.

Plant Energy Biology Fast Facts 2018

- 4 collaborating universities; The University of Western Australia (administrating organisation), Australian National University, The University of Adelaide and La Trobe University.
- 11 Chief Investigators.
- 8 Partner Investigators in USA, Germany, Finland, Sweden and China.
- Partnerships with the Grain Research and Development Corporation, Agilent Technologies, Photon Systems Instruments and Groupe Limagrain.
- Over 200 internationally competitive staff, students and affiliated researchers.
- $26 million from the Australian Research Council and $14 million from partner universities and companies to fund the Centre through to 2020.
- Centre authors contributed to over 80 publications in 2018.

Addressing a critical problem

The world faces three interconnected threats to food security: limited agricultural resources (land, water and key nutrients); a rising human population and *per capita* food consumption; and a yield gap resulting from reduced productivity of crops due to mismatches between crop genetics and unpredictable environments.

PEB recognises that increasing overall 'plant energy efficiency' – the efficiency not only of energy capture, but also of energy conversion and use by plants in order to produce yield – is key to long-term food security.

Plant function is complex. Current international research aims to optimise single-input processes, such as photosynthetic rate or nutrient uptake, in order to increase plant productivity. However, changing inputs alone can reduce the efficiency of downstream processes and thus limit their effectiveness.

The Centre aims to increase the efficiency of energy capture, conversion and use by plants by improving their ability to allocate resources and their tolerance to environmental challenges. Adding efficiency gains together via molecular signalling and control will increase crop plant productivity.

This approach to improving the sustainable productivity of plants will aid in future-proofing food production for Australia and the world.

An innovative research plan

PEB proposes a novel approach to improve sustainable plant yield by optimising their overall efficiency of energy capture, conversion and use. Rather than optimising single nutrient inputs or product outputs, targeting complex processes including plant metabolism, transport, and development for efficiency gains to will be more effective at enhancing overall plant productivity.

Improving multiple parameters simultaneously is a necessary solution to the increasing demand for more crop yield from finite land, water, and nutrient resources. Unpredictable environmental challenges adversely affect plant growth and further perturb plant energy balance, also limiting yield.

The epigenetic controls, gene variants and signals discovered by the Centre will provide a new basis for creating sustainably productive crops that can weather changing and challenging climates.
The enhancement of plant energy efficiency is being approached by PEB through three Research Programs which combine to translate molecular insights into whole plant performance.

These three programs are:

- **P1:** Energy metabolism and signalling
- **P2:** Gatekeeper cells and specialisation
- **P3:** Gene variants and epigenetics

A collaborative effort

The Centre brings together a collection of the world's best researchers from complementary disciplines and integrates scientific research across the range of scales required to truly address the different aspects of the energy efficiency challenge in plants.

Collaborations across Universities and with Industry Partners avoids “reinvention of the wheel” and draws on existing expertise. Sharing our research keeps it at the cutting edge and builds an international network for its application to real world solutions.

The Director's View

In 2018, Plant Energy Biology brought together eleven Chief Investigators from across Australia and eight Partner Investigators from around the world. An increasing PEB Alumni - individuals who have spent important years of their careers at PEB - are now out in the world putting the ethos of blue sky research to the test or applying new knowledge to real world problems by modifying policy, regulation, public education and plant performance. This growing PEB diaspora is one of the most important legacies of the Centre moving into the future.

PEB's exceptional research teams at our host Universities around Australia have continued to make major advances in cell metabolism and signalling regulation, stress response and transport, genome wide association mapping, plant genomics and ecophysiology. Our research is also aiding the Australian grains industry in their aims towards wheat improvement.

Science that makes people think twice

Important milestone publications from the Centre appeared in print in 2018. Our role in unlocking the genome of wheat was revealed in a landmark series of papers in the journal Science. The availability of this high fidelity reference genome will help plant breeders and researchers to accelerate the development of new and improved varieties of wheat with specific characteristics such as higher yield and tolerance to environmental stresses.

We have discovered roles for mitochondria in plants in places that wouldn't have traditionally been looked at. We've identified a role for them in touch responses in plants and in plant recognition of cold temperatures.

We have also revealed how alternative splicing of transcripts can alter proteome diversity to maintain nutrient homeostasis and have gained further insights into how the neurotransmitter GABA has key roles as a stress signal in plants.

Exploiting the potential in these discoveries will be aided by the remarkable possibilities offered by synthetic biology, to use our knowledge to build new capabilities into plants of the future. We now have a growing number of synthetic biologists working and studying in PEB actively building molecular tools for cell design.

Watch this space as the worlds of the biologist and the engineer merge to feed a growing global population. Collaboration drives innovation and it is at the interface of different disciplines that science can lead to some intriguing outcomes. The Centre reaches out to collaborate with scientists nationally and internationally, and to have them lend to our expertise. PEB hosts affiliated researchers from different research areas and promotes collaboration with them.

Our collaborative projects range from new data services for agricultural sciences, contributions in climate modelling, tools for hybrid crop breeding and new strategies for phosphate use efficiency and salt tolerance in crops to match with saline, low nutrient farmland in Australia.

People make science happen

New people joining the Centre brings new research minds to ensure continual rejuvenation of our programs and projects. They are 'the fertilizer needed to make projects flower', applying their different skills and backgrounds to what are often longstanding problems. A key to the Centre's success has been the opportunity for independent researchers to build their projects in collaboration with us.

Our M2I program aids independence, provides flexible skilling and ensures our staff and students build the professional networks needed for the next phase of their scientific journey.

More than 30 Future Fellows, DECRA Fellows and International Fellowship holders have joined the Centre to develop their own research programs since it began. Major papers from these researchers have appeared in top international journals in 2018. Check out some of their achievements in the later pages of this Report.

In 2018, Clarivate Analytics Highly Cited Researcher Awards were announced for four of the Centre's Chief Investigators (Ian Small, Barry Pogson, Rana Munns and myself). Early and mid-career awards were won by postdoctoral researchers Caitlyn Byrt, Joanna Melonek, Stephanie Watts-Williams, Cornelia Hooper and Allison Pearson and several of our PhD students won prizes or awards for their leadership and research skills in 2018.

The Centre is committed to the mentoring of our staff and students and enhancing their skills to help them become independent researchers in the competitive world environment of academia, industry and government. Our pledge in this regard is found in our Mentoring to Independence Program (M2I). A PEB Collaboration Awards scheme was started in 2018 to encourage new projects from PhD and postdoctoral researchers involving cross-nodal collaboration. Six such projects were initiated and we look forward to initial outcomes being presented in next year's Annual Report.

Innovation to impact

As a Centre we largely use tax payer's money as we explore the world around us. It is essential we honour this trust that society has placed in us and use our discoveries to make a difference in the local society we live in and in the global society we depend on. That difference does not always need to be financial, but it does need to be both tangible and explainable.

Combining our expertise and knowledge in partnerships with industry on selected topics of interest to investors and stakeholders can drive such innovation. Salinity tolerance, drought tolerance, phenomics of energy traits, biomarkers in metabolism and plant hybrid systems are the focus of these efforts to date.

In 2018 we upgraded the online “face” of PEB with the launch of our new website. This digital location will serve to best drive the dissemination of our research and stories, draw in the best people and collaborators, and help to connect educators of tomorrow's scientists with valuable teaching resources.

To broaden and deepen the conversations we can have with people from all walks of life and to explain the relevance of what we are doing, we have continued to develop the Virtual Plant Cell (VPC). Through this resource anyone can become immersed in, and interact with, the inner workings of plant cell and in 2018 we focused on bringing VPC into formal educational spaces. VPC helps students to experience the complex processes that our scientists study and consider 'how little things make big things grow'.

During 2018, thousands of people from around the world put on a VR headset to explore VPC, including the Hon. Alanna MacTiernan, Western Australian Minister for Regional Development; Agriculture & Food who spoke as a special guest at our bespoke VPC Showcase event on the value of the program in engaging students in plant and agricultural sciences.

We are rapidly seeing the VPC experience become not just educational entertainment but a valuable teaching resource to capture the imagination of a new generation of plant energy biologists.

Prof. Harvey Millar
Director

CHIEF INVESTIGATORS

PROFESSOR HARVEY MILLAR
(DIRECTOR)

Harvey's research aims to understand the role of respiration in primary carbon and nitrogen metabolism in plants, plant response to oxidative stress and the dynamics of plant proteomes under limiting conditions. Harvey is Centre Director. In 2018 Harvey was named amongst the world's most highly cited researchers.

PROFESSOR IAN SMALL

Ian's research interests involve understanding how plants coordinate the expression of nuclear and organellar genes, and building computational models of plant metabolism. Ian is an ARC Laureate Fellow and a Fellow of the Australian Academy of Science. He was Western Australia's 2014 Scientist of the Year and named one of the world's most highly cited researchers in 2018. He co-leads Research Program 1 with Owen Atkin.

PROFESSOR RYAN LISTER

Ryan's research focus lies in plant and animal epigenomics. Ryan was the 2014 Australian Prime Minister's Awards Life Scientist of the Year. He co-leads Research Program 3 with Justin Borevitz.

PROFESSOR RANA MUNNS

Rana's focus is on the mechanisms by which plants adapt to drought and salinity stress. Rana holds a joint position with the University of Western Australia and CSIRO Agriculture, Canberra. She is a Fellow of The World Academy of Sciences and is recognised internationally for her insights into the fundamental principles of crop adaptation to salinity, and for applications of these insights. In 2018 Rana was named amongst the world's most highly cited researchers.

UWA UNIVERSITY OF WESTERN AUSTRALIA

ANU AUSTRALIAN NATIONAL UNIVERSITY

UA UNIVERSITY OF ADELAIDE

LTU LA TROBE UNIVERSITY

PROFESSOR BARRY POGSON
(DEPUTY DIRECTOR)

Barry's research looks into defining novel roles for carotenoids in plant developmental processes, with complementary research into organelle signalling to identify the mechanisms by which plants perceive and respond to drought and excess light. He was named one of the world's most highly cited researchers in 2018. Barry is PEB's Deputy Director.

ANU

PROFESSOR JUSTIN BOREVITZ

Justin's research applies cutting edge genomics and phenomics approaches to the study of the genetic basis of climate adaptation in plants, and utilises model plants and foundation species in controlled and field environments. Justin co-leads Research Program 3 with Ryan Lister.

PROFESSOR OWEN ATKIN

Owen's research focuses on assessing the impact of environmental gradients on plant physiological processes, particularly respiration. He is the Head of ANU's Division of Plant Sciences and is the interim Director of the Centre for Entrepreneurial Agri-Technology (CEAT). Owen co-leads Research Program 1 with Ian Small.

LTU

PROFESSOR JIM WHELAN

Jim's research combines morphological, biochemical, genetic and 'omic approaches to understand organelle function and biogenesis in plants. Jim is the Co-Director of AgriBio, Agricultural Bioscience. Jim co-leads Research Program 2 with Matthew Gilliham.

PROFESSOR MATTHEW GILLIHAM

Matthew's research focuses on the physiological role of solute transport proteins in plant nutrition and in conferring tolerance to various stresses such as salinity, drought and aluminium. He is the Deputy Head of School for UA's School of Agriculture, Food and Wine. Matt co-leads Research Program 2 with Jim Whelan.

UA

PROFESSOR RACHEL BURTON

Rachel's expertise lies in plant molecular biology and plant functional genomics particularly as it relates to polysaccharide biosynthesis, re-modelling and degradation and the impact these biological processes have on the end use quality of seeds, with focus on human health and nutrition, and biomass feedstocks. Rachel and her laboratory group formally joined PEB in 2018.

PROFESSOR STEVE TYERMAN

Steve investigates the links between ion and water transport in plants and applies his research to grapevine root physiology. Steve is a Fellow of the Australian Academy of Science.

PARTNERS

(Germany)

Max-Planck Institute for Molecular Plant Physiology

The MPI-MP is the elite European institute for research into central plant metabolic pathways, combined with analysis of gene function for development and implementation of phenotyping technologies and system approaches. Mark Stitt and Ralph Bock, two of MPI-MP's Directors, are partner investigators to PEB. MPI-MP has made a substantial commitment to collaborations within the Centre's programs, the provision of facilities for collaboration and to the support of PEB visitors.

(United States of America)

Salk Institute for Biological Studies

The Salk Institute focuses on discovery, and on mentoring future generations of researchers in genetics, cell and plant biology, and related disciplines. Two of its leading research professors, Joseph Ecker and Joanne Chory are partner investigators in PEB. Salk have made in-kind commitments to staff time for collaborations in all programs, to extensive access to facilities and new datasets for collaborations and to the support PEB visitors.

(Sweden)

Umeå Plant Science Centre

UPSC is one of the strongest research environments for basic plant research in Europe and covers a wide range of disciplines in plant biology. UPSC share a common goal to understand the mechanisms driving chloroplast biogenesis and plant adaptation to environments. Åsa Strand, from UPSC, is a partner investigator in PEB. UPSC will provide in-kind commitments in staff time for collaborations, and facilities for collaborations and PEB visits.

(Finland)

University of Turku

The University of Turku houses the Finnish Centre of Excellence in Molecular Biology of Primary Producers. Its Director, Eva-Mari Aro, is a partner investigator in PEB. The Centre will participate through research on chloroplast biogenesis and signalling, and chloroplast function. In-kind commitment will be provided in staff time and facilities for collaborations.

(United States of America)

University of Massachusetts

Umass (Amhurst) is a major US research and teaching university with a strong reputation in plant science innovation. The UMass team, led by Elizabeth Vierling, research temperature responses in plants and will collaborate with PEB to search for new gene networks for temperature tolerance in plants. Additional in-kind commitments will involve follow up work at UMass and the hosting of visiting PEB staff

(France)

Groupe Limagrain

Groupe Limagrain is an international agricultural cooperative group and the world's fourth-largest seed company. It will fund research on controlling male fertility through the manipulation of mitochondrial gene expression. Limagrain is providing wheat germplasm, testing candidate gene sequences proposed by the Centre, and evaluating lines for male fertility and the ability to produce hybrid wheat. Limagrain will provide plant biotechnology development and licensing expertise to PEB.

(Czech Republic)

Photon Systems Instruments

PSI are a leading developer of new technology for imaging of plant growth and development. They will fund the development of instrumentation and new software for use in the Centre, and for deployment across Australia and will bring imaging expertise to a number of Centre's projects.

(Australia)

Agilent Technologies

Agilent Technologies supports advances in life and agricultural sciences, and 'omic analysis and integration as an instrument manufacturer and product developer. The company will work closely with PEB on analytical workflow solutions, automation and robotics in quality control for plant-sample QC analysis, and on refining laboratory management software and analysis. Agilent Technologies will provide analytical product development expertise to PEB's Business Advisory Group.

(Australia)

Grain Research and Development Corporation

The GRDC invests in crop science for the Australian grains sector. GRDC will provide PhD scholarships and research costs to PEB and fund projects arising from CIs' discoveries for improving salinity tolerance and drought tolerance in wheat and barley. The GRDC will give advice to the Centre, evaluate new PEB intellectual property for further funding by GRDC, and will provide knowledge and links for PEB to Australia's grains industry.

(China)

Zhejiang University

ZJU is a major Chinese agricultural university and leads a large research program in increasing phosphate use efficiency in rice. ZJU's partnership role will be in the collaborative development of rice varieties, with emphasis on use of its extensive field sites to facilitate translation from PEB's discoveries. The ZJU collaboration is led by Huixia Shou.

PARTNERSHIP HIGHLIGHTS

Through collaborative efforts with both formal and informal Centre partners PEB broadens its research capacity, draws on global expertise and produces cutting-edge research outcomes.

In 2018, PEB partnerships resulted in a number of significant research publications in top journals.

New perspectives on protein photodamage
[PEB-UWA, University of Turku]

Damage of plant enzymes from high light occurs primarily through the capture and release of energy via photosystems that leads to reversible or irreversible oxidative damage and/or phosphorylation of proteins. This damage has a major economic cost through lowered crop plant growth rates following periods of high light intensity.

Both PEB and University of Turku researchers have an interest and are collaboratively conducting active research into uncovering the full scope of enzymes that are affected in this way. Pivotal to this collaboration is the expertise of University of Turku Primary Investigator Eva-Mari Aro in the different types of inactivation of photosystem I and the research of PEB postdoctoral fellow Dr Lei Li on protein turnover rates in plastids.

By combining our efforts and expertise we have developed a new perspective on the types of proteins that are damaged and a new framework for research to discovery them.

Li L, Aro EM, Millar AH (2018) Mechanisms of photodamage and protein turnover in photoinhibition. TRENDS IN PLANT SCIENCE 23(8):667-76.

Unlocking the genome of bread wheat
[PEB-UWA, The International Wheat Genome Sequencing Consortium (IWGSC), Groupe Limagrain]

Wheat, a key crop for food security, is the most widely cultivated staple on Earth. In 2018, the International Wheat Genome Sequencing Consortium (IWGSC) published the most complete and fully annotated bread wheat reference genome to date.

The availability of this wheat reference genome will help plant breeders and researchers to accelerate the development of new and improved varieties with specific characteristics such as higher yield, tolerance to a stress and resistance to specific diseases.

Among the 202 researchers from 73 research institutions around the globe that were involved in this study were two of PEB-UWA's own. Contributing their expertise in the annotation and analysis of the pentatricopeptide repeat (PPR) protein family - one of the largest gene families in plants - Professor Ian Small and Dr Joanna Melonek identified and annotated almost 2,000 genes within the wheat genome. PEB-UWA researchers are now using the IWGSC reference genome in a collaborative project with formal PEB partner *Groupe Limagrain* to develop hybrid varieties of wheat.

The focus of this work is on a group of PPR proteins, known as *Restorer of Fertility (RF)* proteins, used to control plant fertility during hybrid breeding. Hybrid varieties grow faster and produce more stable yields under difficult environmental conditions, and it is anticipated that gains will be achieved from hybrid wheat varieties becoming available through these partnerships.

International Wheat Genome Sequencing Consortium (2018) Shifting the limits in wheat research and breeding using a fully annotated reference genome. SCIENCE 361(6403).

Unique solutions come from collaboration and the injection of different ideas and expertise.

Technology partnership facilitates discovery in plants

[PEB-UWA, Agilent Technologies]

Succinate dehydrogenase (SDH) plays an important role in mitochondrial respiratory metabolism and in plant defence signalling. The SDH complex must be assembled correctly to ensure enzyme function and as such 'assembly factor' proteins are required by the plant. In 2018, PEB researchers identified At5g67490 as a novel SDH assembly factor in *Arabidopsis thaliana*. Knockout of *At5g67490* (SDHAF4) yielded a mutant plant (*sdhaf4*) with decreases in both SDH activity as well an increased accumulation of succinate.

To better understand how this assembly factor worked, precise measurements of SDH subunits and assembly factors in isolated mitochondrial samples were achieved through both instruments and technical support from our collaboration with industry partner Agilent Technologies. We were able to specifically detect protein abundance for both SDH components and assembly factors for the first time in plants.

This revealed that in *sdhaf4* the level of SDH1 bound to FAD was stable, while another FAD-SDH1 assembly factor, SDHAF2, dramatically increased in abundance, and SDH2 was much lower than the level in wild type plants. This showed that SDHAF4 is required for formation of the SDH1/SDH2 intermediate.

This collaboration enabled us to prove that SDHAF4 acts on FAD-SDH1 and promotes its assembly with SDH2, thereby stabilizing SDH2 and enabling its full assembly with SDH3/ SDH4 to form the functional SDH complex.

The study is a fine example of where the analytical needs of a research project can be coupled with advanced technologies provided by an industry partner to make an important scientific discovery in plants.

Belt K, Van Aken O, Murcha M, Millar AH, Huang S (2018) An assembly factor promotes assembly of flavinated SDH1 into the Succinate Dehydrogenase Complex. PLANT PHYSIOLOGY 177(4): 1439-52.

A visit from UMass's Elizabeth Vierling

[PEB-UWA, University of Massachusetts]

In 2018 PEB had the privilege of hosting Partner Investigator Professor Elizabeth Vierling of the University of Massachusetts in the Centre's Australian National University and University of Western Australia laboratories. Elizabeth's expertise lies in temperature responses in plants.

In collaboration with PEB Chief Investigator Prof. Owen Atkin, Elizabeth conducted experiments examining the links between small heat shock proteins (sHSPs), and whole-plant heat tolerance in Arabidopsis thaliana by exposing genotypes with varying sHSP expression to a simulated heat wave.

Using the National Collaborative Research Infrastructure Strategy (NCRIS) plant growth facilities at ANU, non-invasive image-analysis of plant growth was provided throughout the experiment, and PEB's capacity for high-throughput measurements of respiratory O_2 consumption and photosynthetic heat tolerance was used to explore genotypic differences in heat responses.

Preliminary findings indicate that irrespective of the presence or absence of specific sHSPs, acclimation of growth, respiration and photosynthetic machinery occurs in response to heat. Based on encouraging results, continued experiments are being pursued to assess the functional role of sHSP when plants acclimate to heat wave events.

The best minds and the best tools are focused on addressing plant energy efficiency challenges for the future.

Our Research

What Is Plant Energy Biology?

Much of our food, feed, fibre and fuel is sourced directly or indirectly from plants in the form of energy-containing, nutrient-rich molecules. The synthesis, transport, storage and use of these molecules during plant growth and development is the plant energy system. The efficiency of a plant's energy system determines its final yield of plant products.

The efficiency of the plant energy system can be measured at different levels:

- In cells, as the proportion of energy used for cell maintenance versus growth.
- In whole plants, as the ratio of input resources versus harvestable product.
- In the environment, as the degree of adaptation within plant populations needed to grow successfully in variable conditions.

These measures serve as proxies for plant energy efficiency, an incredibly complex but essential plant trait.

The world urgently requires plants that can more efficiently attain the resources provided by nature and by farmers to generate more harvestable products. Furthermore it needs plants that can to do so on agricultural soils that are decreasing in area and fertility, and that can maintain their performance in harsh and variable environments.

Energy efficiency, which sits at the centre of this requirement, can be gained or lost at multiple levels:

- At the molecular level, in the control of gene expression and metabolic processes.
- At the cellular level, through specialisation and signalling.
- At the developmental level, through physiological responses to the environment.

These gains and losses cumulatively impact across spatial scales, from tissues, to whole plants to plant populations.

The Problem

Presently, even under ideal conditions, elite crops only convert 10–15% of the carbon fixed by photosynthesis into harvestable yield, with even less efficiency seen under harsh environments.

Under suboptimal environments and in certain seasons, crop yields well below potential maxima are observed. In Australia, 60% yield gaps between potential and actual yield are now common. Yields have varied more greatly since 2000 than in any period since 1950. Droughts of moderate severity lead to a 30–70% yield decrease.

The impact of saline soils and temperature extremes ranges from small losses up to complete crop failure, and nutrient-limitation can lead to an 80% decrease in yield.

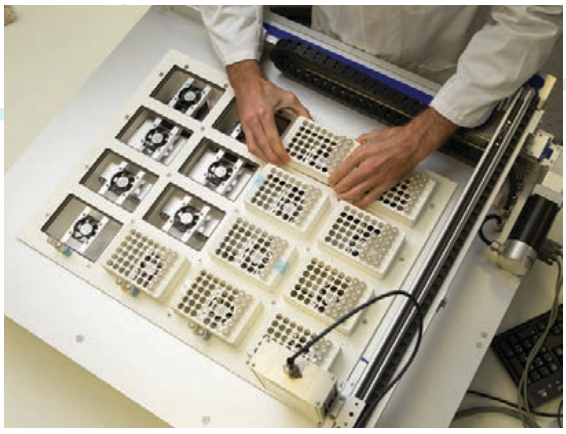
The Solution

Many of these partial losses occur due to limitations and reduced efficiency in interconnected metabolic processes. Thus, small efficiency gains in the multitude of processes beyond carbon capture, but before harvest, can combine to have a magnified benefit on yield.

Discovering the interconnected signalling processes that dictate and limit how plants perform in variable environments is critical to gaining the sustainable increases in actual plant yields that are needed for our future.

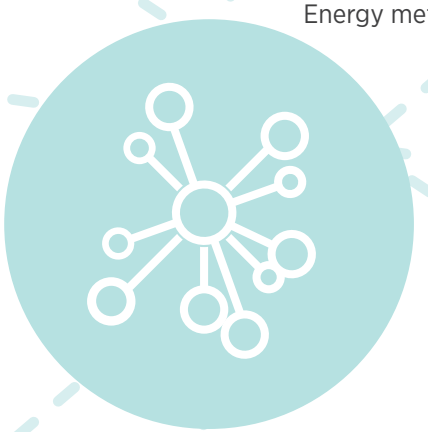
Major targets for efficiency gains include the energy spent on: translocation of carbohydrates and nutrients from leaves to roots and seeds; uptake and storage of nutrients from soils; assimilation and allocation of phosphate, nitrogen and sulphur into proteins, lipids and organics; protein synthesis and turnover and maintenance of cellular ion-gradients.

Tackling plant energy research requires a team with expertise ranging from genes and proteins through to plant physiology. Through our combined expertise and using technological innovation the Centre can enhance the energy efficiency of plants.



Program 1

Energy metabolism and signalling



WHAT NEEDS CHANGING

Metabolic modelling
Signal networks as enviromental sensors
Tuning energy systems in cells for response and resiliance

Program 2

Gatekeeper cells and specialisation

WHERE IT NEEDS TO BE

Gatekeeper cells
Transport and storage
Improving specific cells for whole plant performance

Program 3

Gene variants and epigenetics

HOW WE CAN ALTER IT

Genetic networks
Epigenetic control of plant adaptation
Modifying whole plant genetic networks for variable environments

The Centre is investigating plant energy biology through three linked Research Programs.

Program 1 will define which elements in energy metabolism are the best targets for increasing energy capture and conversion in specific conditions.

Program 2 will define where energy use for resource acquisition in specific cells can have a maximal benefit for the whole plant.

Program 3 will define how networks of genes governing these processes can be identified and manipulated in plant populations for robust responses in limiting environments.

Program one

ENERGY METABOLISM AND SIGNALLING

[PROGRAM 1]

Program leaders: Ian Small and Owen Atkin
Program 1 focuses on cellular functions.

Background

The chloroplast/plastid and the mitochondrion are the two major organelles in plant cells. These organelles co-operate to direct plant cell energy capture and storage of this energy in the form of sugars, starch, oils, protein and fibre - all of which are major agricultural products.

The metabolism of plant organelles underlies the growth and performance of a plant, including its ability to withstand environmental stresses. The Centre has previously shown that chloroplasts and mitochondria are environmental sensors that control growth. Environmental variables such as light, temperature, water and nutrient availability all interact with plant energy systems via signalling processes.

The complex and ancient ways in which organelle function and efficiency are influenced and respond to the environment form the foundation of how plants control conversion of energy to functionally useful forms.

Program Aim

Maximise the efficiency of energy organelles by modelling the efficiency of metabolic strategies in plants, altering the biogenesis of energy organelles and co-opting the signalling processes that control the activity of energy organelles during environmental challenges and recovery

- **Modelling energy processes under varied conditions to choose optimal energy efficiency strategies.**
  Choosing optimal energy efficiency strategies requires a holistic understanding of the costs of building and maintaining cellular machinery and metabolism, which in turn has required the development of integrative models at scales from single cells to whole plants and ecosystems. Examples of application of these models are the simulation and exploration of the genetic basis and metabolic consequences of hybrid vigour, and the examination of temperature responses of leaf energy metabolism over a range of spatial and temporal scales.

  Data for these models comes from measurements of respiration rates and energy costs associated with the major energy-consuming processes in plants, notably synthesis of proteins and cell wall components and transport processes including ion pumps and nutrient assimilation.

- **Modifying energy organelle number, quality and function to improve energy processes in variable environments.**
  The Centre has made great strides in understanding biogenesis of mitochondria and plastids, particularly in the coordination of organellar and nuclear gene expression.

  PEB is now using our understanding of the 'switches' that control energy organelle biogenesis and function to change metabolic outcomes in plant cells, through collaborative research with our partners.

  Combined with a number of established resources, including plant lines with altered organelle biogenesis and growth characteristics, this provides novel opportunities to measure and modify cellular costs and identify new signals of interest.

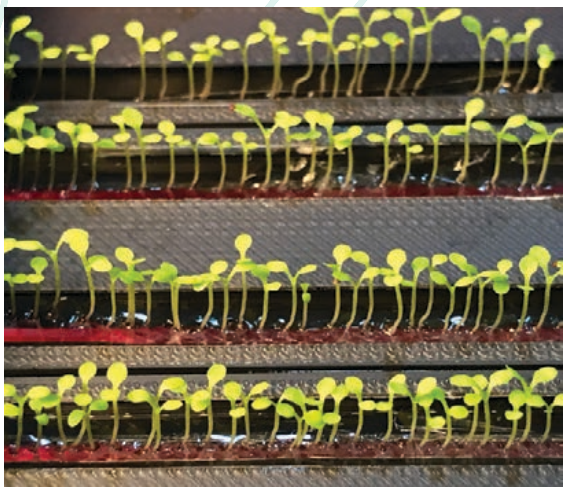
- **Using the receptors and transducers of organelle signals to integrate changes across whole plants.**
  PEB is using signal-protein bait/prey strategies and genetic screens to identify previously unknown steps and components in chloroplast and mitochondrial signalling pathways which contribute to environmental sensing by organelles.

  The Centre is now undertaking research to address whether organelle number or composition can be optimised by regulating signalling networks and whether this can, in turn, optimise plant performance.

  PEB researchers are investigating networks to define what evolutionary boundaries can be jumped and which networks can be rewired without compromising other aspects of energy efficiency.

Regulators of energy efficiency are not directly selected for by most current breeding strategies, meaning there is considerable potential for improvement. Future assisted-breeding of crops requires knowledge of networks of molecular targets that are yet to be discovered.

PEB's research will aid in identifying such targets and lead to enhanced plant energy efficiency for yield by focusing on improvements that can be stacked together for gains in crops.



Personal Success

Dr Joanna Melonek obtained her Masters degree in Poland before moving to Kiel, Germany to complete her PhD studies at the Botanical Institute. She joined PEB as a Research Fellow in 2012. Joanna studies the pentatricopeptide repeat (PPR) protein family of RNA-binding factors in plants, with particular interest in the sub-set called Restorer of Fertility (RF) proteins and their potential applications to hybrid crop breeding.

"I specialise in the identification and characterisation of RFL family members from genomic sequence data from cereals including wheat, barley and rye".

"I'm really interested in the RFL family of PPR proteins as RF proteins have agricultural application in the development of hybrid varieties in plants. Hybrid crop production could help in meeting the future food demands for our growing human population."

2018 was an exciting year for Joanna and the greater wheat community, with the International Wheat Genome Sequencing Consortium (IWGSC)'s publication of the bread wheat reference genome - a project in which Joanna was involved (see PEB Partnership Highlights). In recognition of her contribution, Joanna was awarded a IWGSC Early Career Award and Travel Stipend, facilitating her attendance at the Plant & Animal Genome Conference in San Diego to present her findings to a global wheat genomics and scientific community.

Research Highlight

A mitochondrial role in plant touch responses

In collaboration with researchers from the ARC Centre of Excellence in Plant Cell Walls and colleagues from the VIB Center for Plant Systems Biology, Belgium, a long-term study lead by the laboratory of Chief Investigator Professor Jim Whelan's at PEB's La Trobe University node has uncovered and characterised links between touch (mechanical) stimulation of plants and mitochondrial function. Using a comprehensive set of mitochondrial mutants and mutants for various hormone signalling pathways it was revealed that touch stimulation interacts with abiotic, biotic and growth pathways, altering the transcript abundance of hundreds of genes.

The interaction is complex, with the study revealing several altered patterns of gene expression upon touch, and that different mitochondrial components impacted these patterns differently.

The findings from this technically challenging study showed that in addition to complexity in the touch response at a transcriptome level, touch signalling interacts with the master regulators of energy and stress response signaling pathways that play central roles in determining resource allocation during defense or growth responses in plants.

This study not only raises the question of why plants respond so dramatically to touch but also how much of the energy budget is consumed in this response and whether it could be optimised in agricultural and horticultural species.

The study received significant media attention following its publication in late 2018.

Xu Y, Berkowitz O, Narsai R, De Clercq I, Hooi M, Bulone V, Van Breusegem F, Whelan J, Wang Y (2018) Mitochondrial function modulates touch signalling in *Arabidopsis thaliana*. THE PLANT JOURNAL, 97(4):623-45.

Research Highlight

The enzyme key to crop cold resistance

When a plant experiences cold, how do different parts of its metabolism react?

This question motivated a PEB research effort to identify the enzyme responsible for the cold sensitivity of plant respiration, and in the process identified an enzyme that could be important for frost resistance of crops.

The oxidative phosphorylation pathway (OXPHOS) is responsible for energy production inside of all organisms, including plants. ATP Synthase, a part of OXPHOS, was identified as the rate limiting component during cold stress.

ATP Synthase has a unique mechanism that physically rotates to catalyse ATP production for the plant making it more susceptible to the cold. ATP Synthase inhibition regulates an increase in Alternative Oxidase (AOX). AOX is one mechanism by which plants adapt to cold stress, acting to uncouple OXPHOS from ATP Synthase and thus boosting energy production.

This study has opened up a new understanding of the mechanisms behind cold stress acclimation, the reason for AOX increase in the cold, and the direct detection of temperature changes by the respiratory apparatus.

Kerbler SM, Taylor NL, Millar AH (2018) Cold sensitivity of mitochondrial ATP synthase restricts oxidative phosphorylation in *Arabidopsis thaliana*. NEW PHYTOLOGIST (in press).

Program Two

GATEKEEPER CELLS AND SPECIALISATION

[PROGRAM II]

Program Leaders: Matthew Gilliham and Jim Whelan
Program 2 focuses on cell types and their interactions in plants.

Background

Australia is the most saline continent on Earth. Approximately 69% of the Australian wheat belt is susceptible to the build-up of salts which are inhibitory to plant growth. The extent of worldwide salinity is forecast to increase in the coming decades due to climate change and a greater reliance on marginal land. Meanwhile, global supplies of phosphate are running out. Being an essential macronutrient for plants, growth and yield can be severely limited when phosphate is not supplied as a fertiliser.

Acquisition of necessary nutrients, control of resource transport and the exclusion and cellular detoxification of harmful substances are energy intensive for plants. To secure our future food security we require plants that are more efficient at these processes. Key cell-types often form rate-limiting steps within the transport pathway of nutrients, metabolites and toxins in plant. We call these strategically located cells "gatekeepers".

Program Aim

Improve the efficiency of plant energy use during the acquisition and partitioning of key resources by manipulating the transport properties of gatekeeper cells for water, carboxylates, phosphate, and salt. Single-cell analysis and modification will be used to harness the profound impact these cells have on whole plant energy efficiency in response to deficit or oversupply of nutrients, metabolites and toxins.

- **Optimising energy use in resource acquisition processes.**
  Water and fixed carbon, as resources, are intimately linked to plant energy status. The Centre's research into water and carboxylate transport is exploring the inter-relationship of this with metabolism in specialised gatekeeper cells.

  The control of genes that code for water and carboxylate transport proteins are the new frontier for nutrient acquisition gains. These transport proteins are highly regulated and linked to the energy status of cells, as well as to stresses such as salinity and extreme pH. Reasons for these links are not understood, and the Centre is exploring them as an untapped resource for plant improvement.

  PEB expanded this program in 2018 with the addition of new CI, Prof. Rachel Burton who is leading projects on carbon fate within cell walls and exudation from the plant into the soil. This work is being done in collaboration with other PEB CIs and with Industry to exploit the impact of findings, with particular focus on carbon conversion to soluble fibre for human and animal health.

- **Maintaining cellular energetics optimised under saline conditions through exclusion and tissue tolerance.**
  Soil salinity reduces the energy efficiency of cellular processes including lowering photosynthesis and raising respiration, leading to reduced crop yield. The Centre has previously demonstrated how a single gene can confer improved salt tolerance in wheat without penalty to yield when expressed in specific gatekeeper cells.

  PEB researchers are now discovering parallel pathways to further optimise crop productivity within saline environments through specialised cell types. This work is enhanced by the Centre's access to unique Australian cereal genotypes and the mapping of populations differing in key traits that underpin salinity tolerance.

- **Altering phosphate uptake, storage and use as keys to the energy currency of cells.**
  Phosphate is needed in plant energy metabolism as a component of high-energy molecules. The Centre, however, aims to design proof-of-concept plants that maintain biomass and yield under low phosphate conditions.

  Forward and reverse genetic approaches are being used to identify the mechanism(s) by which plants maintain growth under low or limiting phosphate supply. Approaches combine cell specific targets for compounds involved in phosphate status signalling, regulators of the proteins that control phosphate homeostasis, and the regulatory genes for phosphate starvation identified through genome and epigenome analysis.

  These approaches are revealing a variety of mechanisms utilised by plants to respond to limiting phosphate, and that targeting genes that are expressed in cell specific manner leads to increases in plant biomass accumulation in limiting Pi conditions.ass accumulation in limiting Pi conditions.

Program 2 links to Program 1 through the use of cell specific energy flux measurements, and through the assessment of organelle enhanced plants on nutrient acquisition and toxin tolerance. Findings will inform the generation of crops better suited to a changing agricultural landscape.

Personal Success

Having collaborated with PEB since 2014, **Dr Allison Pearson** formally joined the PEB team in 2017 as a Postdoctoral Fellow in the laboratory of CI Matthew Gilliham. Allison grew up in Mildura, on the Murray River at the border of New South Wales.

"Being a part of a farming family I hope that the research we do will make a difference, so the prosperity of Australian farming can continue".

Allison's research forms part of the Centre's International Wheat Yield Partnership (IWYP) project. She is responsible for the project's extensive phenotyping experiments, as well as the construction of a genetic map to determine regions of the wheat genome involved in a plant's energy use so that this information might be applied to improving a wheat plant's ability to divert energy into yield.

Allison's successes since joining PEB include a 2017 and a 2018 Australian Grains Industry Trust (SAGIT) grant and a 2018 YITPI Foundation Crop Science Research Grant.

Personal Success

As a postdoctoral Research Fellow at PEB's University of Adelaide node, **Dr Rakesh David's** focus is on the use of artificial intelligence (AI) techniques to improve the long term sustainability of biological databases. Biological databases have become indispensable tools for researchers to access the latest, high-quality data in their field. In 2018, Rakesh's team was awarded a UA Interdisciplinary Research Grant to develop a proof-of-concept AI platform.

"As biologists, we use databases on almost a daily basis to guide our research. More often than not, this data is manually curated by experts in the field".

"In the age of big data, this task is becoming increasingly difficult and time-consuming. Our goal is to take advantage of recent advances in Natural Language Processing and deep learning to automate the curation process, thereby keeping databases relevant for a long period of time."

Rakesh's project involves an exciting technology partnership with Microsoft to integrate their advanced cloud computing services into database analysis.

Research Highlight

Role for alternative splicing in responses to nutrient deficiency

In addition to CO_2 and H_2O, plants require a variety of macro and micro nutrients to grow. Availability of such nutrients is finite and routinely a limit to growth within agricultural systems. Plants respond to nutrient deficiency by optimising their uptake through a variety of means. Traditionally, such responses have been investigated by looking for differences in transcript abundance for various genes. In addition to changes in abundance, Alternative Splicing (AS) represents a means to alter proteome diversity, and is important for a number of developmental processes in both plants and animals.

In a study published by PEB and colleagues in 2018, whole transcriptome RNA sequencing was used to analyse responses to the absence of iron, zinc, copper, manganese, and phosphorus in rice, with a focus on not only gene transcripts that changed in abundance, but in transcripts that were alternatively spliced.

The study revealed 13,291 genes that had alternatively spliced forms, representing ~50% of multi-exon genes in the rice genome. Furthermore, the overlap between differentially expressed genes and differentially alternatively spliced genes was small, suggesting that looking at differentially expressed genes only partially reveals the story of a plant's response to nutrient limitation.

Dong C, He F, Berkowitz O, Liu J, Cao P, Tang M, Shi H, Wang W, Li Q, Shen Z, Whelan J, Zheng L (2018) Alternative splicing plays a critical role in maintaining mineral homeostasis in rice (*Oryza sativa*) THE PLANT CELL 30(10): 2267-85.

Research Highlight

Plant use of an animal chemical in stress response

In 2018, PEB researchers and colleagues from University of Adelaide reported that they had uncovered a key mechanism in the response of plants to stresses in their environment. Earlier studies showed that plants respond to environmental stresses with a similar combination of chemical and electrical responses to that of animals. The mammalian neurotransmitter gamma-aminobutyric acid (GABA) is produced by plants under stress conditions such as drought or salinity, and acts in a similar fashion as it does in animals, but through plant specific systems.

What remained unclear was how and why GABA levels changed in plants. By manipulating internal GABA levels using drugs that regulate GABA in animals, the researchers discovered a relationship between GABA levels in plants and the activity of a wheat transport protein important in acid soil tolerance. The study showed that expression of this protein reduced GABA levels in plant root cells within toxic soil by allowing it to move out of the cells. It is believed that this process allows the degree of stress to be communicated across cells, enabling a metabolic response to stress for the plant.

Understanding the role of GABA as a stress signal provides a new tool in efforts to breed more stress-tolerant crops. Further, in light of crossovers in the GABA-signalling system between plants and animals, future work on plant GABA signalling agents could potentially benefit the medical field.

Ramesh SA, Kamran M, Sullivan W, Chirkova L, Okamoto M, Degryse F, McLauchlin M, Gilliham M, Tyerman SD (2018) Aluminium-activated malate transporters can facilitate GABA transport. THE PLANT CELL 30: 1147–64.

Program

GENE VARIANTS AND EPIGENETICS

[PROGRAM III]

Program Leaders: Ryan Lister and Justin Borevitz
Program 3 focuses on plants in populations and across generations.

Background

Across diverse habitats, plant populations fine-tune their energy systems to withstand and exploit changing environmental conditions. Natural genetic diversity contains many adaptive traits. The molecular basis of these traits can now be mined from plant genomes by unifying modern genomics technologies with precision phenotyping and environmental monitoring and control across 1000s of individual plants.

In addition to determining the genetic components underlying complex traits of an organism, it may be important to understand the epigenetic codes that govern where and when the genetic information is used. Epigenetic modifications that do not alter the genome sequence but that can regulate the readout of the underlying genetic information may be environmentally sensitive and/or heritable.

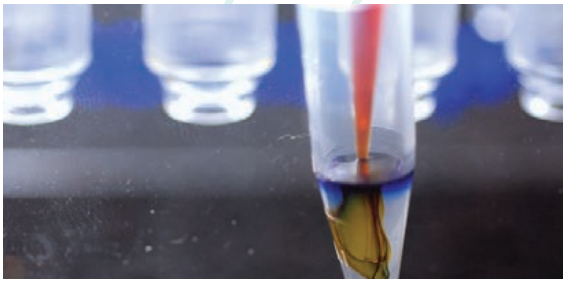
Knowledge of the underlying variation that governs complex plant functions will allow selection and engineering of plants for future variable environments to be done with far more precision.

Project Aim

Identify genetic and epigenetic control of energy efficiency during plant growth by dissecting out adaptive phenotypic variation in natural populations of plants. We are using genome wide association studies across dynamic environments simulating future local growing conditions.

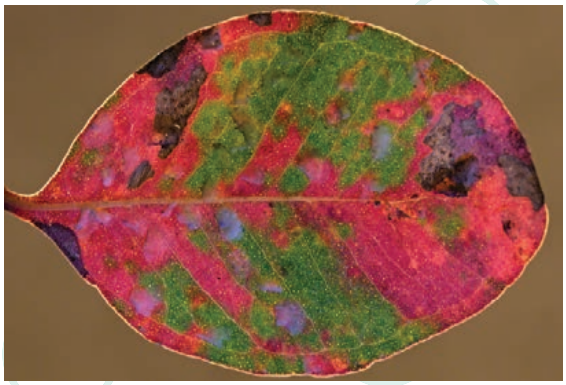
- **Exploiting (epi)genetic variation to define the gene networks and gene variants that determine energy efficiency.**
  The historical selection of plants for high yield in optimal environments has resulted in elite varieties that often do not possess the resilience found in natural populations. We can now tap into a more wild molecular genebank of (epi)genetic solutions to challenging environments.

  The Centre is driving major advances in tools to precisely dissect out these (epi)genetic solutions from natural populations of plants. This will clarify the contribution of the (epi)genome to natural variation in plant energy systems and the molecular basis of how plants transform energy to grow and survive in changing and challenging environments.



- **Developing new tools for precision editing of genome activity to engineer plant energy efficiency.**
  To further study and manipulate genes and cellular signalling pathways the Centre aims to develop new genome regulatory tools. Novel approaches to construct artificial gene circuits through adaptation genome editing technologies will allow more sophisticated control of gene expression and ultimately whole pathways in order to deliberately manipulate plant cell function in response to multiple input signals.

We are targeting phenotyping of dynamic plant responses to changing environments and conditions, with specific focus on light, drought, temperature extremes and nutrient-limitation. Our approaches will enable the design, breeding and selection of plants that with altered growth and energy efficiency under limiting and variable conditions of the future.



Personal Success

Dr Suvi Honkanen is one of PEB's CSIRO SynBio Future Science Fellows. In the laboratory of CI Ian Small she is applying the emergent field of Synthetic Biology to improving plants. Specifically she is developing synthetic PPR proteins as tools to control protein translation in the plant chloroplast. She is utilising the novel "simple plant" model system Marchantia, an organism she studied during her PhD research.

"Since joining, I have set up Marchantia as a model system at PEB and really appreciate all the help and resources I've got from my previous colleagues".

"PEB and the Small group have been very welcoming and I've learned a lot about organelles and protein engineering"

"My evo-devo and bryophyte background is probably a bit unusual here, but being able to bring some diversity to the team can be an advantage".

The Marchantia system is now being utilised by other researchers in PEB.

Personal Success

Dr James Lloyd joined the PEB team in 2018 as a Research Associate in the laboratory of CI Professor Ryan Lister. Originally from the UK, James' career in the plant sciences started when he won a Sainsbury Studentship in Plant Sciences from the Gatsby Charitable Foundation during his undergraduate studies. An interest in RNA biology took him to the University of California, Berkeley following his PhD studies, where he became fluent in computational analysis of the large datasets being produced by transcriptome sequencing experiments. Following this position, his desire to return to the lab bench and the field of plant sciences, but with the application of his computational skills led him to join PEB to work on synthetic biology. James is now applying his knowledge of gene regulation to creating synthetic gene circuits.

"I have always been interested in how things work at their most basic level. This is why I like genetics and am excited about synthetic and engineering biology."

"If we understand something, then we should be able to build it. And if we keep iterating over a problem then each iteration yields new knowledge".

Research Highlight

Successful restoration through genomic modelling

As species face rapid environmental change, resilient populations can be built through restoration projects that incorporate predicted future climates into seed sourcing decisions. In 2018, the Centre's first study towards developing a method for landscape genomic prediction of climate and soil suitability for plant foundation species was published.

In order to identify a small but significant signal of isolation by distance and by environment, PEB researchers examined genomic variation in hundreds of Eucalyptus plants from dozens of Australian locations. While conservation practice recommends using local seed collection sources for woodland restoration the results for this study uncovered tremendous variation within large populations that span 500km. Broad regions along the north or south coast could be differentiated as more sensitive to climate shifts than inland or alpine regions. This corresponded with projected changes in seasonal moisture and temperature.

The study provides a tool for restoration practitioners to identify regions for seed sourcing that account for genomic variation suitable for predicted future climates, thereby increasing the long term probability of successful restoration.

Supple MA, Bragg JG, Broadhurst LM, Nicotra AB, Byrne M, Andrew RL, Widdup A, Aitken NC, Borevitz JO (2018) Landscape genomic prediction for restoration of a Eucalyptus foundation species under climate change. eLIFE pii: e31835.

Research Highlight

Building molecular tools for cell design

Epigenetic modifications are vital in regulating transcription and cell identity. DNA methylation is a key epigenetic modification that is involved in diverse biological processes including plant development and in suppressing viral fragments of DNA, called transposable elements (TEs). Changing the epigenome to build better plants and crops is an important technology that has tremendous potential for future applications. Consequently, molecular tools are needed to precisely edit the epigenome for cell design. However, first-generation molecular tools suffer based on catalytically dead CRISPR/Cas9 (dCas9) fused directly to molecular effector domains and exhibit pervasive off-target effects.

In collaboration with the Laboratory Group of Professor Jose Polo at Monash University, PEB researchers developed an improved dCas9 based epigenome editing tool to specifically change DNA methylation in the genome of cells with the highest precision reported to date. They leveraged this technology to establish that certain transcription factors were sensitive to DNA methylation in their binding sites, and that induced changes in DNA methylation at the target genes resulted in reduced transcription.

This work will fundamentally advance our understanding of transcriptional regulation and will transform our ability to control the epigenetic regulatory layers of the genome, with immense benefits for cell identity manipulation and design.

Pflueger C, Tan D, Swain T, Nguyen T, Pflueger J, Nefzger C, Polo JM, Ford E, Lister R (2018) A modular dCas9-SunTag DNMT3A epigenome editing system overcomes pervasive off-target activity of direct fusion dCas9-DNMT3A constructs. GENOME RESEARCH 28(8):1193-206.


Excellence in science is about refining our ideas and expertise until we discover solutions to difficult problems.

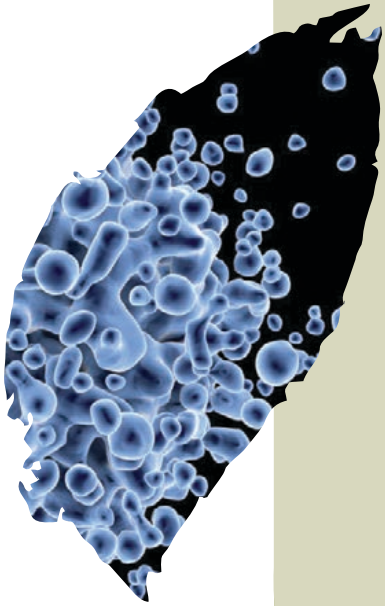
Impact

TRANSLATION OF RESEARCH TO APPLICATION

Tools For Hybrid Crop Breeding

The use of hybrid crop varieties is increasing because of their attractive agronomic traits. Development of hybrid breeding systems requires a means to control self-pollination. Cytoplasmic male sterility (CMS) and fertility restoration is one approach that has been exploited, but the lack of suitable restorer genes has been a major limiting factor. Work by the Centre has identified PPRs as the major group of *restorer of fertility (Rf)* genes in plants and is developing approaches to find effective natural variants and to design synthetic ones.

By identifying *Rf* genes in genomic data from cereals (including wheat and sorghum) the Centre is helping its partners to use this approach to restore male fertility. Our partners, including Limagrain, University of Queensland and the U.S. Department of Agriculture, will test candidates in field trials. We believe this approach will be valuable to plant breeding companies keen to develop new hybrid varieties, particularly in crops where such hybrids have been difficult to create.



Genomic Approaches For Phosphate Use Efficiency Improvement

Phosphate remains a major cost as a fertiliser and a significant limiter of plant growth in harsh nutrient-limited environments. We still require fundamental knowledge of how plants gain and retain phosphate in order to make them more efficient users of this limiting resource.

Three "genomic" approaches are being undertaken by the Centre to make discoveries to alter the phosphate relations of plants. Firstly an iterative analysis of co-expression, enrichment and protein-interaction networks is being used to identify novel, cell-specific regulators of phosphate uptake and use in plants. Secondly, we are screening Arabidopsis accessions for differences in responses to phosphate limiting conditions. Thirdly we are using SPX4-Luc in a forward genetic screen to identify regulators of phosphate sensing. These projects are aimed to identify novel genes for Phosphate Use Efficiency in plants that can be transferred to our academic or commercial partners for evaluation and study under field conditions.

Relevant modelling of climate

The Centre is working at the frontline of plant research that utilises systems to model dynamic climatic conditions in physiologically and ecologically relevant ways. The research team has developed pipelines that enable high throughput studies under dynamic environmental conditions using growth chamber technology.

Spectral climate chamber facilities enable the fine control of light intensity and spectrum, temperature and moisture to simulate local and regional field-like conditions from particular locations and seasons. Refining the use of such systems equips the Centre with the means to perform future work in climate analogues that mimic specific growing regions with climate change scenarios, greatly enhancing translation of the Centre's discoveries to real-world application.

These systems are being developed by the Centre not only for important small plants such as *Arabidopsis* and *Brachypodium,* but also for crop plants, such as wheat and foundation species such as Eucalyptus. In 2018 we received the first of four larger grow capsule climate containers as part of a new facility with extra high light and energy efficiency, in order to grow populations of plants under simulated field conditions.

Growing more for less – energy use efficiency for wheat yield

To address the need for dramatic global crop yield increases in order to meet future food security needs, the Agriculture Ministers of the G20 nations established the International Wheat Yield Partnership (IWYP) - a unique, multi-national funding initiative to co-ordinate wheat research efforts globally.

The PEB-led IWYP project *Improving Wheat Yield By Optimising Energy Use Efficiency* is using teams at UWA, UA and ANU to examine the relationship between photosynthesis, respiration, growth and yield in order to exploit the energy systems of wheat plants and dramatically increase their productivity. Along with partners at the ARC Centre of Excellence in Translational Photosynthesis and the International Maize and Wheat Improvement Centre (CIMMYT) the team is using hyperspectral measurements of photosynthesis, high-throughput measures of respiration, biochemistry and genetics, along with field-based physiological measurements in a novel approach to screen wheat populations and identify new yield-related traits.

Since the project's commencement, glasshouse trials in the Adelaide Plant Accelerator and five field trials in Mexico and Canberra have been completed, over fifteen-hundred cultivars screened, over two-fold differences in respiration rates identified and proteomic and metabolomic analysis of many hundreds of samples conducted. The information is being applied to produce new models of energy efficiency and novel markers and hyperspectral measures that can be deployed in breeding programs to enhance wheat yield potential.

Building Salt Tolerant Crops

Many commercial crops are sensitive to soil salinity, causing major yield losses every year. The Centre has led a number of studies aimed at increasing salinity tolerance in crop plants important to the Australian economy including wheat, barley, soybean and grapevine.

GmSALT3 was identified by Centre researchers as a gene conferring salt tolerance to soybean plants and this information can now be used in breeding programs to ensure that tolerance is maintained in future cultivars of soybean that will be grown in areas prone to soil salinity. Furthermore, the novel way in which this gene was found to confer salt tolerance is driving the search for similar genes in different crops such as wheat and grapevine to selectively breed for their own enhanced salt tolerance.

New insights on the wheat HKT protein – uncovered in one of the foundation studies of the Centre as responsible for excluding toxic sodium ions from the shoot – has shown how the structure of this protein results in its effectiveness to transport sodium and confer salt tolerance.

The Centre for Entrepreneurial Agri-Technology (CEAT)

A major initiative to emerge in 2018 from PEB was the Centre for Entrepreneurial Agri-Technology (CEAT), based at the Centre's ANU node. Opened in August 2018, CEAT now operates separately from PEB, but with a beneficial mission to create a collaborative innovation ecosystem and to bring together plant/agricultural scientists with researchers from the environmental and computer sciences, engineering, business and economics, in order to best develop technological solutions for challenges being faced in modern agriculture.

CEAT will foster a proactive culture and develop an integrated system that facilitates more effective translation of research findings into agricultural practice, policy or impact. The formation of CEAT was led by researchers from PEB, with Professor Owen Atkin its interim Director.

CEAT intends to showcase career opportunities in Agri-tech to students and researchers from a wide range of disciplines, including those in PEB and will support researchers in translating their research by financially supporting staff and students to participate in incubator and accelerator programs to assist with the development and implementation of appropriate business models. A *CEAT Innovation Hub* on the ANU campus will support direct interaction of researchers and students with start-ups, small-medium enterprises (SME) and multi-national companies.

WHERE ARE THEY NOW?

PEB's ALUMNI

PEB's have fostered many researchers, students and professional staff over the Centre's history who have gone on to take up successful positions around the globe, within and outside the world of science. The current positions of just some of PEB's alumni are highlighted here.

Raising the next generation of researchers and leaders with the skills to solve global challenges...

Lei Li
Then: PhD Student and Postdoctoral Researcher
Now: Professor and Lab Head
Organisation: College of Life Sciences, Nankai University
Country: China

Ralitza Alexova
Then: ARC Super Science Fellow
Now: Education Team Coordinator
Organisation: Muzeiko Children's Science Museum
Country: Bulgaria

Corey Worcester
Then: Operations Manager
Now: Centre Manager
Organisation: Centre for Social Research and Methods, Australian National University
Country: Australia

Richard Jacoby
Then: PhD Student and Research Associate
Now: Marie Curie Postdoctoral Fellow
Organisation: Botanical Institute, University of Cologne
Country: Germany

Tim Stuart
Then: PhD student
Now: Postdoctoral Fellow
Organisation: New York Genome Center
Country: USA

Sandra Kerbler
Then: PhD student
Now: Postdoctoral Researcher
Organisation: Max Planck Institute of Molecular Plant Physiology
Country: Germany

Kai Xun Chan
Then: PhD Student and Postdoctoral Fellow
Now: Marie Curie Postdoctoral Fellow
Organisation: UGent Center for Plant Systems Biology, Vlaams Instituut voor Biotechnologie
Country: Belgium

Olivier Van Aken
Then: Postdoctoral Fellow
Now: Associate Professor and Lab Head
Organisation: Lund University
Country: Sweden

Yun Shin (Michelle) Sew
Then: PhD student
Now: Senior Scientist
Organisation: Malaysian Agricultural Research & Development Institute (MARDI)
Country: Malaysia

Jared Streich
Then: PhD student
Now: Postdoctoral Researcher
Organisation: Oak Ridge National Laboratory
Country: USA

Boris Baer
Then: Affiliated Future Fellow & Lab Head, CIBER
Now: Professor and Lab Head
Organisation: Center for Integrative Bee Research, University of California Riverside
Country: USA

Katharina Belt
Then: PhD student
Now: Postdoctoral Fellow
Organisation: The Commonwealth Scientific and Industrial Research Organization (CSIRO)
Country: Australia

Pip Wilson
Then: Postdoctoral Researcher
Now: Program Officer
Organisation: Grains Research and Development Corporation (GRDC)
Country: Australia

Peter Kindgren
Then: Postdoctoral Fellow
Now: Postdoctoral Fellow
Organisation: Department of Plant and Environmental Sciences, University of Copenhagen
Country: Germany

John Rivers
Then: PhD student
Now: Genetic Technologies Officer
Organisation: Grains Research and Development Corporation (GRDC)
Country: Australia

Sam Henderson
Then: PhD Student and Postdoctoral Researcher
Now: Postdoctoral Fellow
Organisation: The Commonwealth Scientific and Industrial Research Organization (CSIRO)
Country: Australia

Olivier Keech
Then: Postdoctoral Researcher
Now: Associate Professor and Lab Head
Organisation: Department of Plant Physiology, Umeå University
Country: Sweden

Szymon Kubiszewski-Jakubiak
Then: PhD student
Now: Postdoctoral Researcher
Organisation: Max Planck Institute of Molecular Plant Physiology
Country: Germany

Kate Howell
Then: Postdoctoral Fellow
Now: HDR Education Coordinator
Organisation: The University of Notre Dame
Country: Australia

Norman Warthmann
Then: Postdoctoral Researcher
Now: Plant Molecular Geneticist
Organisation: Plant Breeding and Genetics Laboratory, FAO/IAEA
Country: Austria

Ozren Bogdanović
Then: Postdoctoral Fellow
Now: Senior Research Fellow & Lab Head
Organisation: Garvan Institute of Medical Research
Country: Australia

Johannes Scharwies
Then: PhD student
Now: Postdoctoral Fellow
Organisation: Stanford University
Country: USA

Simon Law
Then: PhD student
Now: Postdoctoral Researcher
Organisation: Department of Plant Physiology, Umeå University
Country: Sweden

Science and innovation are an important part of everyone's future. Providing our community with access to accurate information and creating positive public dialogue about science is vital.

Science Communication

Education, Outreach, Media and Training

To facilitate a better and more widespread understanding of the importance of plants, PEB uses its unique Education, Outreach, Media and Training programs and resources to link the community with plant energy biology and the Centre's research.

We strive to inspire students, teachers, end-users, policymakers and the general public through the delivery of engaging, informative and novel science programs. PEB also aims to equip its researchers with the skills and resources necessary to broadly and effectively communicate their science and engage in dialogue with the Australian community.

Outreach

PEB's outreach programs use novel resources to engage audiences and highlight the role of plant energy biology in everyday life and the importance of our research.

Virtual Plant Cell (VPC), PEB's newest education and outreach experience, capitalises on cutting-edge virtual reality technology to teach plant cell biology and communicate our research in a fun, innovative and engaging way. Viewed by over 100 thousand people since its inception, VPC serves as a fantastic platform for dialogue between our scientists and the community and is a highly effective educational tool. *See 2018 highlights for the VPC program, pages 34-35.*

Outreach Highlight
A Boutique Botanical event

In collaboration with Questacon, the National Science and Technology Centre, we hosted two intimate, boutique PEB events for ACT's adult public and teachers in the Questacon Q Lab. The events featured PEB's ACT Scientist of the Year, Dr Kai Chan, and fellow plant scientists from PEB and the ARC Centre of Excellence for Translational Photosynthesis.

The *A Boutique Botanical* adults-only event journeyed attendees through exciting ways of improving plants for our future, and highlighted important links between plant research and the glasses of gin that were poured for visitors!

A Teachers Only event provided ACT teachers with innovative activities, resources and real-world examples to inspire their students with and connect them to the power of plants.

Plant Powerstation is a key resource for PEB's community education and outreach. Our staff facilitate visitor engagement in hands-on learning activities and interact with members of the community as part of public display stalls.

Plantarium, an immersive, full-dome visual showcase of PEB and its research, is routinely played in combination with Q&A sessions with PEB scientists where enthusiastic audiences can learn about PEB's research and have their questions addressed.

Bio-Bounce, a unique education resource created by the Centre, is the world's biggest and bounciest plant cell. The inflated structure houses elements of a plant cell and allows for an immersive, educational experience led by PEB staff.

Education

Enthusing the next generation about plant science and science careers, and creating advocates for scientific discovery is a major aim of the Centre. PEB engage school-aged students in a number of ways, including through school incursions with visiting PEB scientists and workshops and laboratory-based excursions to educate about and discuss our research.

Powerful Plants, a multi-faceted, hands-on science program that teaches scientific method, critical thinking and the importance of plant research has been a two time runner up in the WA Premier's Science Awards. Hundreds of primary and secondary students in South Australia and Western Australia engaged in Powerful Plants in 2018. Students took part in messy and exciting hands-on experiments and learned about the power of plants, what DNA is and the effects of salt on plants.

PEB's ANU scientists continued their extensive involvement in the Melrose Senior High School's Academic Curriculum Enrichment (ACE) science program in 2018. The program is an advanced, novel science program for year 8 to 10 students. PEB's involvement in the program includes visits to the school, presentations by PEB scientists, tours of PEB facilities and mentorship of select students as part of the ACE Mentors Program.

Education Highlight

A Powerful Plants Science Experience

PEB researchers had the pleasure of engaging 84 science-loving Year 9 and 10 students in a day of hands on activities. The students, many from country South Australia, visited the University of Adelaide Waite Campus as part of the Conoco Phillips Science Experience. The PEB team introduced students to exciting aspects of the research being conducted by the Centre, including addressing ways for plants to cope with stress.

Students got hands-on, extracting DNA from blackberries, performing stomatal peels from beans and tradescantia leaves to compare guard cells under the microscope and exploring the Virtual Plant Cell.

"We hope we encouraged some students to pursue studies in plant science!" says Dr Rebecca Vandeleur.

Media

PEB recognises that the Australian media is an avenue to achieve broad community reach for the communication of our science. In 2018 the Centre continued its valuable affiliation with the Australian Science Media Centre (AusSMC) and a presence on Scimex, the online breaking science news portal for Australia and New Zealand.

In 2018 PEB achieved over 130 online, television and radio media commentaries, and continued the use of its established social media platforms to promote PEB science and have a dialogue with the community.

The Centre also launched a new website (www.plantenergy.edu.au) to best showcase PEB, its personnel, research and resources online. A PEB Outreach sub-site is enhancing our reach and quality of engagement with Australian and international educators.

Media Highlight

An on-air demo of gene technology

Professor Rachel Burton appeared in the ABC Catalyst two-part series 'Feeding Australia', an exciting, documentary series that explored innovations in food and agriculture to sustainably feed a growing population into the future.

The ABC Catalyst team visited the Waite Campus at the University of Adelaide, where Rachel demonstrated to host Professor Clare Collins the mechanism behind the gene technology CRISPR-Cas9. Using a fun, hands on model of DNA, Rachel was able to show how the technology can be used to edit plant DNA.

"I think there's a massive potential for CRISPR and I think that we're going to think of some very smart ways to apply it" said Rachel.

The Series aired on ABC and iView, with the first episode broadcast on Tuesday 14 August for National Science Week.

VIRTUAL PLANT CELL

2018 was a highly successful year for the Virtual Plant Cell (VPC) project. In 2018, the Centre focused efforts on purposing this expanding suite of immersive and interactive, science-informed experiences for classroom use.

By providing a virtual taste of applied plant science, our curriculum-aligned VPC resources aim to enhance STEM education through the introduction of novel technologies into the classroom, and inspire the next generation of scientists towards career paths focused on advancing crop improvement and global food security.

In recognition of the impact that VPC is having in educational engagement it was named a 2018 finalist for the prestigious Western Australian Premier's Science Awards, Science Engagement Initiative of the Year, and for a TIGA Games Industry Award (Educational Game).

Ground-breaking VPC trial with Trinity College

The development of our first, fully-interactive, curriculum-aligned *Virtual Plant Cell: Classroom VPC* experience was completed in 2018. Built for Oculus Rift technology, the resource complements the Year 8 Australian cell biology curriculum.

A ground-breaking pilot study, conducted with our partner school Trinity College, Perth, and researchers from the University of Western Australia examined the *Practicality and Efficacy of using Virtual Reality to Teach Plant Cell Biology* using Classroom VPC.

Lessons run with over 70 students clearly demonstrated the educational impact that VPC can have, as well as an ability to stimulate engagement and interest in plant cell biology. The student and teacher response to VPC has been overwhelmingly positive.

"It is amazing and really helped me to understand what the inside of a plant cell really looks like, rather than just the teacher explaining it to me in class."

"I feel like incorporating VR in education makes it a fun way to learn information. It makes me more interested in actually learning about the plant cells rather than just learning it from a textbook."

Through our partnership with Trinity College, VPC is now a staple student experience in the school's state-of-the-art Virtual Reality (VR) Classroom.

VPC in the hands of teachers

To stimulate the uptake of VPC for education, PEB hosted a teacher Professional Development workshop on *VPC and VR for the Classroom* in 2018. Teachers from around Western Australia who participated reported that they were keen to take VPC back to their students. A PEB Outreach website, launched in 2018, is now providing online access to an extensive suite of VPC Teaching Resources for Australian and international educators.

A Virtual Plant Cell Showcase

In late 2018 the Centre promoted VPC to Government, the Education Sector and Industry at a bespoke *Virtual Plant Cell: A showcase of a leading virtual reality initiative for Australian STEM education* event. The afternoon featured advocacy and a special address from the Honourable Alanna MacTiernan, Western Australian Minister for Regional Development; Agriculture & Food.

"We need more people to understand that agriculture is an exceptionally important and exciting area" she said.

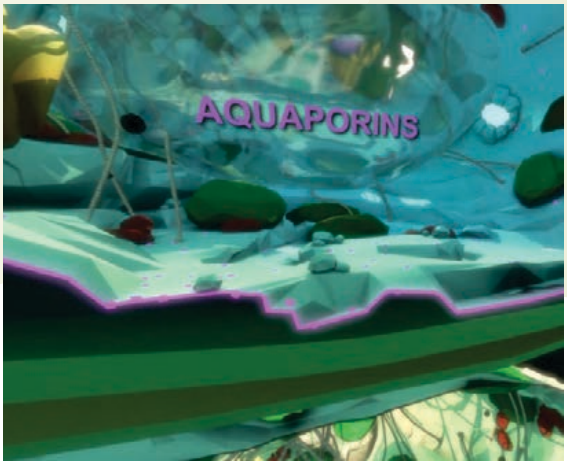
"There's no doubt that this technology offers a pathway into engagement"

VPC out and about

The use of VPC paired with our well-established, innovative public program Plant Powerstation has proven to be a great, synergistic approach to our community engagement and outreach. In 2018, VPC made public appearances during major National Science Week festivals around Australia, at University Open Days and for Campus Science Outreach. VPC was taken into schools for incursions led by PEB scientists, effectively engaging thousands in the exciting inner world of plants.

Educational partnerships for VPC

Through an exciting partnership with Stile Education we made *VPC: Explore a Cell* available to over 250,000 Australian school-aged students through Stile's science lessons platform for 2018 and beyond. *VPC: Drought Proof*, our first curriculum-aligned VPC teaching resource, was launched to educators at a boutique science event held in partnership with Questacon, Australia's National Science and Technology Centre.



VPC resources are now a feature on The Australian Academy of Science's comprehensive online website for high school sciences, *Science by Doing.*

In collaboration with our colleagues at the *ARC Centre of Excellence for Translational Photosynthesis* (TP) we created *VPC: Into Aquaporins*.

This 360° video features as a key piece in TP's Planting Science: Classifying Systems in Cells lesson plan resource, highlighting inspirational research and researchers from both Centres of Excellence.

National and International VPC

VPC visited Australian Parliament House in 2018! The Australian Research Council's Making a Difference Showcase saw a VR headset donned by the likes of Senator Andrew Laming and ARC CEO Professor Sue Thomas as they went on to explore the virtual cell.

VPC also made international appearances, with two of our VPC films featuring as part of the VR SciFest in Stockholm Sweden and subsequently translated into Russian to tour cities around Russia for the FANK: Festival of Contemporary Science Cinema.

Efforts are now underway to translate VPC into Bulgarian for use at the Muzeiko Children's Museum, and into Thai for distribution by In-Budget. By the end of 2018, our online VPC experiences ticked over 100,000 views by the international public.

We pride ourselves on bringing together a multi-disciplinary, multi-cultural and diverse research team to focus on a common challenge.


People

"I am delighted to join the talented team at PEB.

This is an opportunity for a whole new set of ideas and expertise to help progress our collective research. We are all looking forward to forging fruitful collaborations across the Centre.

Welcoming CI Rachel Burton

In 2018 PEB welcomed its newest Chief Investigator, Professor Rachel Burton. Rachel and her team have transitioned into the Centre's University of Adelaide node, joining CIs Prof. Steve Tyerman and Prof. Matthew Gilliham.

Rachel brings with her expertise in plant molecular biology and plant functional genomics, particularly as it relates to cell wall biosynthesis, re-modelling and degradation and the impact these biological processes have on the end-use quality of grains, seeds and biomass.

She is interested in the development and application of novel experimental methods for transcript profiling and gene discovery and gene editing in plants.

She is particularly interested in cellulose synthases, the mixed link β-glucan synthases and the xylan synthases. Amongst other projects, Rachel will be involved in research to understand the energy cost of cellulose synthesis, the transport of precursors to make cellulose and the role of cellulose as a major investment by the plant, influencing its form, function and stress tolerance.

In 2018, Rachel and her team contributed to a number of significant publications, including the discovery of two new polysaccharides in plants and a novel cellulose synthase-like gene family in dicots.

Rachel co-authored the review article *Root cell wall solutions for crop plants in saline soils* with other members of PEB. The publication highlights the effects of salt stress on cell wall modifying enzymes, and cell wall changes linked to tolerance to salt-stressed and water limited roots.

Rachel also brings to the Centre her strong track record and focus on training and mentoring students and early career researchers, and on community and social media outreach.

She was named a Science and Technology Australia Superstar of STEM for 2017/18.

PEB welcomes the valuable addition of new expertise and fresh perspectives brought by Rachel and her team and the benefits that this will bring to the Centre's research programs.

Byrt CS, Munns R, Burton RA, Gilliham M, Wege S (2018) Root cell wall solutions for crop plants in saline soils. PLANT SCIENCE 269(4):47-55.

PEB Students

PEB is committed to excellence in its recruitment, training and education of postgraduate students.

PEB recognises the crucial part its postgraduate students play in the Centre's success. Investing heavily in opportunities for our students to engage in technical and professional courses and training programs that enhance knowledge and skills prepares them for positions in the commercial and academic sectors and leads to successful outcomes for the Centre through the work of these high-achievers.

The Centre boasts 95 PhD, Masters and Honours students enrolled during 2018, 38 of whom commenced and 28 who successfully completed in the year. PEB students claimed a number of awards and authored numerous publications in 2018.

Student Highlight

Dr Diep Ganguly has had a substantial career with PEB, commencing in the original Centre in 2009 as a Laboratory Technician. Following a successful Honours degree completed at PEB, Diep commenced a PhD project at PEB's ANU node focusing on mechanisms of transcriptional control for stress acclimation in plants.

2018 saw Diep publish a first-author manuscript in Plant, Cell and Environment, co-author a publication in Plant Physiology, upload a co-first authored manuscript to *BioRxiv* and co-supervise several students. He also gained recognition as an Associate Fellow of the Higher Academy of Education.

"A curiosity about the hype surrounding genetic modification and biotechnology led me to pursue this field at University" says Diep.

He recalls first meeting Prof. Barry Pogson during the first year of his undergraduate studies when Diep asked several questions about plant stress signalling. He was offered the Technical position at this time and has been associated with PEB since.

"PEB provides a great place to do research. It's a focal point of excitement, expertise, and collaboration to make fundamental discoveries".

Upon the 2018 completion of his PhD studies, Diep transitioned into a role as a Postdoctoral Fellow with PEB and is examining post-transcriptional mechanisms of controlling gene expression, such as mRNA stability and translational regulation.

PEB Affiliates

PEB extends its research and builds new collaborations through its valued affiliated researchers. Our affiliated researchers are independently funded and bring both added expertise and an expanded focus to PEB. The Centre in turn provides support, access to technology and collaborative opportunities for these scientists and their staff and students.

Affiliate Highlight

Dr Mark Waters is a molecular geneticist who is studying the mechanisms behind hormone perception in plants. As an ARC Future Fellow within UWA's School of Molecular Sciences and an Affiliate Researcher to PEB, he leads a small research group studying various aspects of hormone signalling and response.

Mark's research draws upon Arabidopsis genetics, synthetic biology and transcriptomics, and is supported by the expertise and facilities within PEB. He has been affiliated with PEB since 2010 when he joined the laboratory of Prof. Steven Smith – a CI of the former PEB Centre - as a postdoctoral researcher. Over the intervening years, Mark has developed a successful, independent research program, while finding continued benefit in the intellectual atmosphere and collective mass of plant researchers afforded by his affiliation with PEB. The Centre in turn benefits greatly from Mark's expertise and the research activity that his team brings.

"I've been enormously fortunate to find a home at PEB, which contains such a concentration of talented individuals with related research interests."

"PEB has played a significant part in my success to date, which would have been harder without ongoing access to reliable instrumentation, facilities and support staff."

Some of Mark's recent research includes a detailed genetic analysis of the karrikin receptor protein in plants (Yao et al. 2018, *Plant Journal*). This work revealed regions of the protein essential for different aspects of the protein's function, improving our understanding of how the receptor operates in a molecular context. Mark's research also relies heavily on the local expertise in chemistry and structural biology that comes from the close association of his laboratory and PEB with other affiliated researchers co-housed at UWA.

"The combination of plant molecular sciences with organic and analytical chemistry in the same building – even on the same floor – is really powerful. It has encouraged me to build research leads that otherwise would have been impractical or beyond my means, and really helps to extend the reach of PEB's influence."

AWARDS & RECOGNITIONS

Allison Pearson	CASS Travel Award	CASS Foundation
Amanda Philpot	Sally and Andrew Smith prize, best presentation	School of Agriculture, Food, and Wine, University of Adelaide
Barry Pogson	2018 Highly Cited Researcher	Clarivate Analytics
Caitlin Byrt	ASPS Peter Goldacre Award	Australian Society Plant Scientists
Cornelia Hooper	ONprime Innovation Award	CSIRO
Derek Collinge	Joint Colleges of Science Professional Staff Award 2018, Outstanding Individual Performance	College of Science, Australian National University
Derek Collinge	Vice Chancellors Commendation for Innovation (Service & Solutions)	Vice Chancellor, Australian National University
Glenda Oh	Caroline Stewart Young Memorial Prize in Agriculture	Faculty of Science, University of Western Australia
Harvey Millar	2018 Highly Cited Researcher	Clarivate Analytics
Ian Small	2018 Highly Cited Researcher	Clarivate Analytics
Jacinta Watkins	The Crawford Fund International Agriculture Student Award	The Crawford Fund
Joanna Melonek	Fay Gale Fellowship	University of Western Australia
Joanna Melonek	IWGSC Early Career Award	International Wheat Genome Sequencing Consortium (IWGSC)
Joanna Melonek	IWGSC Travel Award	International Wheat Genome Sequencing Consortium (IWGSC)
Julia Grassl	Rising Star 2018 Award, third prize	Faculty of Science, University of Western Australia
Matthew Gilliham	Research Leadership Award	Faculty of Sciences, University of Adelaide
Rana Munns	Slatyer Medal	Australian National University
Rana Munns	2018 Highly Cited Researcher	Clarivate Analytics
Sam Buckberry	Raine Research Prize	Raine Medical Research Foundation
Stephanie Watts-Williams	The Edith Dornwell ECR Excellence medal	Faculty of Sciences, University of Adelaide
Stephanie Watts-Williams	Women's Research Excellence Award	University of Adelaide
Virtual Plant Cell	2018 Chevron Science Engagement Initiative of the Year, finalist	Premier's Science Awards, Department of Jobs, Tourism, Science and Innovation, Government of Western Australia
Virtual Plant Cell	Games Industry Award (Educational Game), finalist	TIGA

PEB's team of exceptional researchers and staff excel not only in their work but in their related endeavours. For this they are routinely recognised and in 2018, PEB's scientists and staff were the recipients of a range of prestigious awards and recognitions.

VC's Commendation

Dr Derek Collinge was recognised in 2018 for having redefined his position as Laboratory Manager for PEB, within the ANU Research School of Biology, in order to extend his impact beyond the lab. He was awarded the Vice Chancellor's Commendation for Innovation (Service & Solution) by the Australian National University's VC. Derek has a strong, solutions-driven work ethic and initiates team-based problem solving processes that have helped drive forward the research and careers of many students and early career researchers.

"I've always been a facilitator of research," he says.

"By helping to solve the day-to-day problems of students, early career researchers and academics alike, I afford them more time to undertake world-class research and achieve their full professional and personal potential."

He has redefined the ways the Centre interacts with professional staff and, driven by his passion for science, has helped to lead many of PEB's outreach activities in the ACT. Derek is also an avid photographer and has used his skills to capture the essence of plant biology, winning multiple awards for his science communications photography.


Eureka!

Nominations for the prestigious Australian Museum Eureka Prizes were made for two of PEB's own in 2018. **Dr Caitlin Byrt** was a finalist for the Macquarie University Eureka Prize for Outstanding Early Career Researcher, while **Professor Barry Pogson** was a finalist for the University of Technology Sydney Eureka Prize for Outstanding Mentor of Young Researchers. Barry has had a significant impact on the personal development, career prospects and learning experiences of students at all tertiary levels.

"My vision is to create a nexus of researchers, industry leaders and policy makers that collectively shape agriculture for the benefit of global food security".

Caitlin's Early Career track record has focused on research to address the agricultural issues of rising salinity and more frequent drought. Dr Byrt's research has identified sodium transport genes, which are now being used globally to produce salt tolerant crops that are better adapted to changing environments.

The Australian Museum Eureka Prizes reward excellence in the fields of research and innovation, leadership, science engagement and school science.

SCIENTIFIC ADVISORY COMMITTEE

A Scientific Advisory Committee (SAC) of six scientists and end-user representatives assist and guide the Centre.

Emeritus Professor Ian W. Dawes FAA (SAC Chair)
School of Biotechnology and Biomolecular Sciences, UNSW Australia

Emeritus Professor Dawes' research career has focused on the response of eukaryotic organisms to oxidative stress and ageing, the molecular analysis of control of one-carbon and folate metabolism in yeast and the mechanisms involved in initiation and timing of cell development. He is an editor of the journal FEMS Yeast Research and a member of the editorial boards of Yeast and the Journal of Microbiology.

Em. Prof. Dawes has been a Board Member of the Victor Chang Cardiac Research Institute and of the Australian Proteomic Analytical Facility and Chairman of the International Yeast Genetics and Molecular Biology Community. He has a BSc from the University of New South Wales, a DPhil from the University of Oxford in the UK and is a Fellow of the Australian Academy of Science.

Professor Fiona Cameron
College of Science, ANU, Australia

Following more than 20 years in active research, Professor Cameron's established the CSIRO Emerging Science Unit for Nanotechnology, moving into the CSIRO National Research Flagship for Food Research and subsequently established the Innovation Unit of the University of Western Sydney. She subsequently held the position of Executive Director at the Australian Research Council (ARC). In her role she was responsible for the Biological Sciences and Biotechnology (BSB) discipline, the BSB College of Experts and for oversight of major investment programs including Centres of Excellence, Industrial Transformation Research Program and Special Research Initiatives.

Prof. Cameron holds an Honorary Professorship at the College of Science, at the Australian National University (ANU) and currently consults personally. She is a Senior Associate at "Outside Opinion" and sits on two research advisory committees in addition to that of PEB.

Dr Juan Juttner
Grains Research and Development Corporation, Australia

Dr Juttner was a Postdoctoral Fellow at the Australian Centre for Plant Functional Genomics at University of Adelaide before moving to the Grains Research Development Corporation (GRDC). He has held a number of Project and Senior Management positions at the GRDC and is now the Senior Manager for Genetic Technologies. In his role he develops sound Research and Development (R&D) strategies and delivers targeted solutions to industry requirements. He applies technical, commercial, financial and intellectual property due diligence knowledge to plan and procure optimal investments.

In addition, Dr Juttner engages growers and industry stakeholders to secure a path to market for investment outputs and maximise investment impact. He has practical experience in establishing and leading the external and internal teams required to deliver broad organisational objectives.

Professor Dale Sanders FRS
John Innes Centre, Norwich Research Park, UK

Professor Sanders is Director of the John Innes Centre, internationally regarded as one of most prestigious plant and microbial sciences research centres. His career has focused on plant cell responses to environment and on plant cell nutrient acquisition and storage. He is a leading authority on mechanisms for the transport of chemical elements across plant cell membranes - mechanisms that have key roles in the control of crucial crop traits such as nutritional value, seed germination, response to drought conditions and plants response to toxins.

Prof. Sanders also works on the fundamental science of specialised plant transport mechanisms involved in signalling which have important, but poorly understood roles in plant biology. In 2001 he was elected as a Fellow of the Royal Society and awarded the European Science Prize of the Kärber Foundation.

Dr Tina Barsby OBE
NIAB, Cambridge, UK

Dr Barsby is the CEO of NIAB, previously the National Institute of Agricultural Botany, following almost 20 years of working for the Limagrain Group. Dr Barsby is a plant geneticist, well-known for her significant experience in the agricultural crop sector. Her strong leadership skills and supportive staff have enabled her to position NIAB as an internationally recognised and innovative organisation, operating under the strapline 'Plant Science in to Practise'.

Dr Barsby is committed to the translation of plant science into products and services of value to industry and to society at large. She is an Associate of the Royal Agricultural Society and was awarded an OBE in the 2018 New Year's Honours List for services to Agricultural Sciences and Biotechnology.

Dr Allan Green
CSIRO Agriculture & Food, Sydney, Australia

Dr Green has devoted his lifetime career at CSIRO to understanding genetic control of oil and fatty acid biosynthesis in plants, for application towards new and improved oil crop products for agriculture. Formally trained in agricultural science, he has been a pioneer in using increasingly sophisticated genetic technologies for the modification of fatty acid composition in oilseed crops to provide improved nutritional value and novel industrial end uses.

Dr Green founded the CSIRO Plant Oil Engineering Group and provided strategic leadership that has moved it to the forefront of global research into improved plant oil production. Their recent development of technology for synthesising and accumulating high levels of oils in plant leaves is a dramatic modification in plant energy biology, with potential to create new oil-producing energy crops capable of sustainably delivering advanced biofuels cost-competitively with petroleum-based fuels. Dr Green will shortly retire from full-time research and take up an Honorary Research Fellow role at CSIRO Agriculture & Food, based in Sydney.

UNIVERSITY OF WESTERN AUSTRALIA

Abzalov	Aygul	PhD Student
Bates	Tiffane	Affiliated Bee Yard Manager
Bernath-Levin	Kalia	Affiliated Research Associate
Boykin	Laura	Affiliated Research Fellow
Brar	Kamalpreet	PhD Student
Broda	Martyna	PhD Student
Buckberry	Sam	Affiliated Postdoctoral Research Associate - ECR
Cahn	Jonathan	PhD Student
Cao	Hui	PhD Student
Castleden	Ian	Database/Systems Engineer
Christiana	Staudinger	Affiliated Researcher
Colas des Francs-Small	Catherine	Research Associate
De Mendoza	Alex	Research Fellow
Dissanayake	Bhagya	PhD Student
Duffy	Ciara	PhD Student
Duncan	Owen	Affiliated Postdoctoral Researcher
Farthing	Rosemarie	Laboratory Technician
Fenske	Ricarda	Research Officer
Fisher	Mark	PhD Student
Gill-Hille	Mabel	Honours Student
Grassl	Julia	Affiliated Postdoctoral Research Associate
Gutmann	Bernard	Affiliated Researcher - DECRA
Haywood	Joel	Research Associate
Holt	Shannon	PhD Student
Honkanen	Suvi	Research Associate/CSIRO Fellow - ECR
Hook	Rochelle	Administrative Officer
Hooper	Cornelia	Postdoctoral Researcher
Huang	Shaobai	Affiliated ARC Future Fellow
Huynh	Dang Sang	PhD Student
Ivanova	Aneta	Affiliated Research Associate
Karpievitch	Yuliya	Research Associate
Kelly	James	Honours Student
Khan	Adil	PhD Student
Kidd	Brendan	Research Associate/CSIRO Fellow
Kinene	Tonny	PhD Student
Kotra	Vinay	Masters Student
Kratz	Madlen	PhD Student
Kwok Van Der Giezen	Farley	Honours Student
Le	Xuyen	PhD Student
Lee	Alex	Postdoctoral Researcher
Lee	Xin Chien	Masters Student
Li	Lei	Postdoctoral Researcher - ECR
Lister	Ryan	Chief Investigator
Lloyd	James	Postdoctoral Researcher
Marsh	Jacob	Honours Student
Mayor	Alfred	Masters Student
Mcdowell	Rose	PhD Student
Melonek	Joanna	Research Fellow
Millar	Harvey	Director and Chief Investigator
Mohamed	Sufyaan	PhD Student
Moran	Jessica	PhD Student
Moss	Dylan	PhD Student
Munns	Rana	Chief Investigator
Murcha	Monika	Affiliated ARC Future Fellow
Mylne	Joshua	Affiliated ARC Future Fellow
Nguyen	Trung	PhD Student
Oh	Glenda	PhD Student
O'Leary	Brendan	Affiliated Researcher - DECRA
Oliva	Marina	Postdoctoral Researcher ECR
Palanivelu	Nithya	PhD Student
Pang	Pauline	Masters Student
Petereit	Jakob	PhD Student
Pflueger	Christian	Postdoctoral Researcher-ECR
Pflueger	Jahnvi	Laboratory Manager
Poppe	Daniel	Research Associate - ECR
Price	Karina	Science Communications Officer
Pruzinska	Adriana	Affiliated Researcher DECRA

UNIVERSITY OF WESTERN AUSTRALIA (CON'T)

Roffa	Issa	Honours Student
Royan	Santana	PhD Student
Salih	Karzan	PhD Student
Shute	Geetha	Chief Operations Officer
Simmons	Rebecca	PhD Student
Small	Ian	Chief Investigator
Small	Ghislaine	PhD Student
Ströher	Elke	Affiliated Researcher
Stuart	Tim	PhD Student
Sun	Kelly	PhD Student
Swain	Tessa	PhD Student
Tang	Ting	Affiliated Graduate Research Assistant
Tang	Anqiang	PhD Student
Tang	Dave	Research Fellow - ECR
Tang	Sunday	Masters Student
Tanz	Sandra	Affiliated Researcher - DECRA
Taylor	Nicolas	Affiliated ARC Future Fellow
Tonti-Filippini	Julian	Affiliated Research Associate
Vargas Landin	Dulce Beatriz	PhD Student
Vincis Pereira Sanglard	Lilian Maria	PhD Student
Wainaina	James	PhD Student
Walker	Hayden	IT Officer
Wallace	Michael	Honours Student
Wang	Yimin	PhD Student
Waters	Mark	Affiliated Future Fellow
Wijerathna Yapa	Akila	PhD Student
Yeoman	Deborah	Accounts and Purchasing Officer
Zhong	Xiao	PhD Student

AUSTRALIAN NATIONAL UNIVERSITY

Almonte	Andrew	Technical Officer
Alves Negrini	Ana Clarissa	Postdoctoral Researcher - ECR, Laboratory Manager
Asao	Shinichi	Research Associate
Atkin	Owen	Chief Investigator
Borevitz	Justin	Chief Investigator
Bothwell	Helen	Postdoctoral Researcher ECR
Bowerman	Andrew	Affiliated Research Associate ECR
Cao	Michelle	Honours Student
Carmody	Melanie	Affiliated Researcher/CSIRO Fellow
Chai	Ming-Dao	Honours Student
Chan	Kai Xun	Postdoctoral Researcher - ECR
Coast	Onoriode	Research Associate
Collinge	Derek	Laboratory Manager
Cullerne	Darren	Affiliated Research Associate - ECR
Drieberg Wilkins	Hannah	Honours Student
Fan	Yuzhen	PhD Student
Ferguson	Scott	Honours Student
Gaju	Reshmi	Affiliated Research Associate
Ganguly	Diep	Postdoctoral Researcher - ECR
Garcia	Andreas	PhD Student
Hammer	Julia	Honours Student
Hawley	Naomi	Projects and Operations Officer
Hazel-pickering	Sarah	Laboratory Technician
Hou	Xin	PhD Student
Jones	Ashley	Technical Officer
Khin	Nay Chi	PhD Student
Leroux	Julie	PhD Student
McQuinn	Ryan	Postdoctoral Researcher - ECR
Moore	Marten	Technical Officer
Murray	Kevin	PhD Student
Phua	Su Yin	Postdoctoral Researcher - ECR
Pogson	Barry	Deputy Director and Chief Investigator
Posch	Brad	PhD Student
Reddiex	Adam	Postdoctoral Researcher - ECR
Scafaro	Andrew	Postdoctoral Researcher - ECR
Simonsen	Anna	Affiliated Researcher - DECRA
Smith	Aaron	PhD Student
Srivastava	Akansha	PhD Student
Stanley	David	Honours Student

AUSTRALIAN NATIONAL UNIVERSITY (CON'T)

Stone	Beth	Technical Officer
Streich	Jared	PhD student
Tee	Estee	PhD Student
Watkins	Jacinta	PhD Student
Xiong	Xiaofeng	PhD student
Yadav	Arun	Affiliated Postdoctoral Researcher - ECR
Yee	Suyan	Honours Student
Zhai	Deping	PhD Student

UNIVERSITY OF ADELAIDE

Balacey	Suzanne	PhD student
Bose	Jayakumar	Affiliated Researcher - DECRA
Burton	Rachel	Chief Investigator
Byrt	Caitlin	Affiliated Researcher - DECRA
David	Rakesh	Affiliated Researcher - ECR
Feng	Xueying	PhD Student
Ford	Melanie	PhD Student
Gill	Alison	Honours Student
Gilliham	Matthew	Chief Investigator
Gowder Shekharappa	Chethana	PhD Student
Herliana	Lina	PhD Student
Kamran	Muhammad	PhD Student
Khor	Shi Fang	Research Assistant
Long	Yu	Postdoctoral Researcher
Mafakheri	Ali	Laboratory Manager
McGaughey	Samantha	PhD Student
McKay	Daniel	PhD Student
Meng	Ying	PhD Student
Neumann	Kylie	Research Assistant
Pearson	Allison	Affiliated researcher
Phan	Hoai Thi Thanh	PhD Student
Philpot	Amanda	PhD Student
Piechatzek	Adriane	PhD Student
Qiu	Jiaen	Postdoctoral Researcher - ECR
Qu	Yue	Postdoctoral Researcher - ECR
Ramesh	Sunita	Postdoctoral Researcher
Sai	Na	PhD student
Schnell	Nicholas	Honours Student
Schulz	Jakob	PhD student
Shelden	Megan	Affiliated researcher - DECRA
Sohaimi	Muhammad Khairul Hisyam Ahmad	PhD Student
Sullivan	Wendy	Laboratory Manager
Tyerman	Stephen	Chief Investigator
Vandeleur	Rebecca	Operations and Research Manager
Watts-Williams	Stephanie	Affiliated Research Fellow - ECR
Wege	Stefanie	Affiliated Researcher - DECRA
Wu	Yue	PhD student
Xu	Bo	Affiliated Researcher -ECR

LA TROBE UNIVERSITY

Berkowitz	Oliver	Research Fellow
Hartmann	Andreas	PhD Student
Haslem	Asha	Research Associate
He	Cunman (Frank)	PhD Student
Jain	Ritushree	Research Associate
Jost	Ricarda	Research Fellow
Li	Lu	PhD Student
Liew	Lim Chee	Research Associate
Linn	Joshua	Research Fellow
Lozano	Diego	PhD Student
Lyu	Wenhui	PhD Student
Meng	Xiangxinag	PhD Student
Narsai	Reena	Affiliated Researcher - DECRA
Osorio	Marina Borges	PhD Student
Ren	Meiyan	PhD Student
Selinski	Jennifer	Research Officer
Wang	Yan	Research Fellow
Whelan	James	Chief Investigator
Xu	Yue	Research Officer
Yi	Changyu (Joe)	PhD Student
Zhou	Xishi	Visiting Fellow
Zhu	Yanqiao	Visiting Fellow

SELECTED 2018 CENTRE PUBLICATIONS

2018 Publication Fast Facts

- Total number of publications by Centre staff: 82
- Average impact factor: 7.2
- Publications in top journals (impact factor 10 and above): 13
- Top journals include: Nature, Science, Nature Communications, Trends in Plant Science, Genome Research, Nature Plants and The Plant Cell.

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