ANNUAL REPORT 2017

Genes to Energy | Energy to Yield

plant energy **biology**
ARC CENTRE OF EXCELLENCE

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BRINGING TOGETHER THE BEST MINDS AND THE BEST TOOLS TO FOCUS ON A COMMON CHALLENGE.

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 2017

- 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 2017.

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 2017 Plant Energy Biology entered the second half of its funding from the Australian Research Council, which will see the Centre through till 2020. The Centre's ten Chief Investigators have expanded to eleven with the welcoming of Professor Rachel Burton from the University of Adelaide, and our Partner Investigators have extended from seven to eight with Professor Huixia Shou joining as a partner from Zhejiang University, China.

Our highly productive research teams continue to make major advances in cell metabolism and signalling regulation, stress response and transport, genome wide association mapping, plant genomics and ecophysiology.

Our strategic research is also aiding the Australian grains industry in their aims for wheat improvement. We continue to strive to appoint the right people, to pursue the right projects and have an eye both to discovery and application in evaluating our results.

People make the difference

New people joining the Centre means new research minds to ensure programs and projects are rejuvenated regularly, being watered and fed by different skills and backgrounds. The Centre creates opportunity for independent researchers to build their projects in collaboration with us, and take advantage of the exciting intellectual environment and the modern facilities at each of our four university partners.

More than 25 Future Fellows, DECRA Fellows and International Fellowship holders have joined the Centre to develop their own research programs since it began. For many of these their first papers since joining PEB appeared in top international journals in 2017. Another set of four independent researchers joined in 2017; notably two researchers with CSIRO Synthetic Biology Fellowships.

> 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.

In 2017, two of our Chief Investigators were announced as Highly Cited Researchers (Ian Small and Barry Pogson) and Tall Poppies were named in the ACT, SA and WA (Kai Chan, Jayakumar Bose and Monika Murcha). Notably, Dr Chan was also named as 2017's ACT Scientist of the Year. Nine of our PhD students won prizes or awards for their leadership, teaching and mentoring.

Our pledge to foster the skills and independence in our staff and students for success underpins our Mentoring to Independence Program (M2I). Through a series of events and opportunities M2I aims to aid independence, provide flexible skilling and ensure our staff and students build the professional networks needed for the next phase of their scientific journey.

> Collaboration drives innovation and it is at the interface of different disciplines that science can lead to some intriguing outcomes.

Breakthrough science

Key Centre projects reached the important milestone of publication in 2017. The Centre rivals many of the world's best known and respected plant science centres when using citations as a metric of the wide interest in our results. Centre investigators, postdoctoral researcher and students have been in demand as presenters at over 25 international conferences this year.

2017 saw our research programs and progress reviewed by the Australian Research Council, providing us a valuable opportunity to revamp, reorganise and develop new goals in the strategic direction of our research. New research on transport systems, that use much of the chemical energy transformed in cells, has been initiated.

Much wider use of environmental simulation facilities and of genomic and epigenomic profiling of plant cells are being undertaken as we seek to explore the gene networks that control energy efficiency of plants at the level of individual cells. Experimental flux analysis and modelling activities are being used as we quantify the cellular economy of plant systems at new levels of depth.

PEB hosts affiliated researchers from different research areas and promotes collaboration with them. The Centre also reaches out to collaborate with scientists nationally and internationally to lend our expertise. In 2017 we welcomed a new research group from the CRC for Honey Bee Products, who are collaborating with us on immunity biomarkers for honey bee health that will be important for future food security.

These projects range from new data services for agricultural sciences, to development of a genetic similarity estimator, to contributions in climate modelling and to the use of our biological or technical expertise to aid discoveries by medical researchers in applications far from plant science.

Impact is a goal

As a Centre we ultimately want our discoveries to make a difference in the local society we live in and in the global society we depend on. To do this we use our expertise and knowledge in partnerships with industry on selected topics of interest to investors and stakeholders. Salinity tolerance, drought tolerance, phenomics of energy traits, biomarkers in metabolism and plant hybrid systems are the focus of these efforts to date.

To broaden and deepen the conversations we can have with people from all walks of life, 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. VPC helps audiences to experience the complex processes that our scientists study and consider 'how little things make big things grow'.

During 2017 thousands of people have donned a VR headset to see what all the fuss is about. We are now working to make our virtual reality experience into a valuable teaching resource.

Professor 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 2016 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 2017. 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.

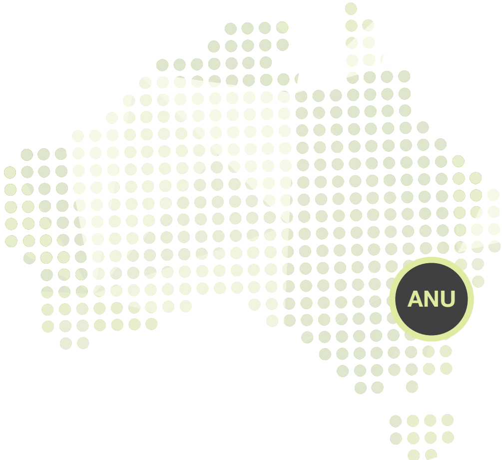
PROFESSOR RANA MUNNS

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. Rana 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.

- **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 2017. Barry is PEB's Deputy Director.



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. Owen co-leads Research Program 1 with Ian Small.

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, Centre for Agricultural Bioscience and was named amongst the world's most highly cited researchers in 2016. 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 an ARC Future Fellow, and co-leads Research Program 2 with Jim Whelan.

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 formally joins PEB in 2018.

PROFESSOR STEVE TYERMAN

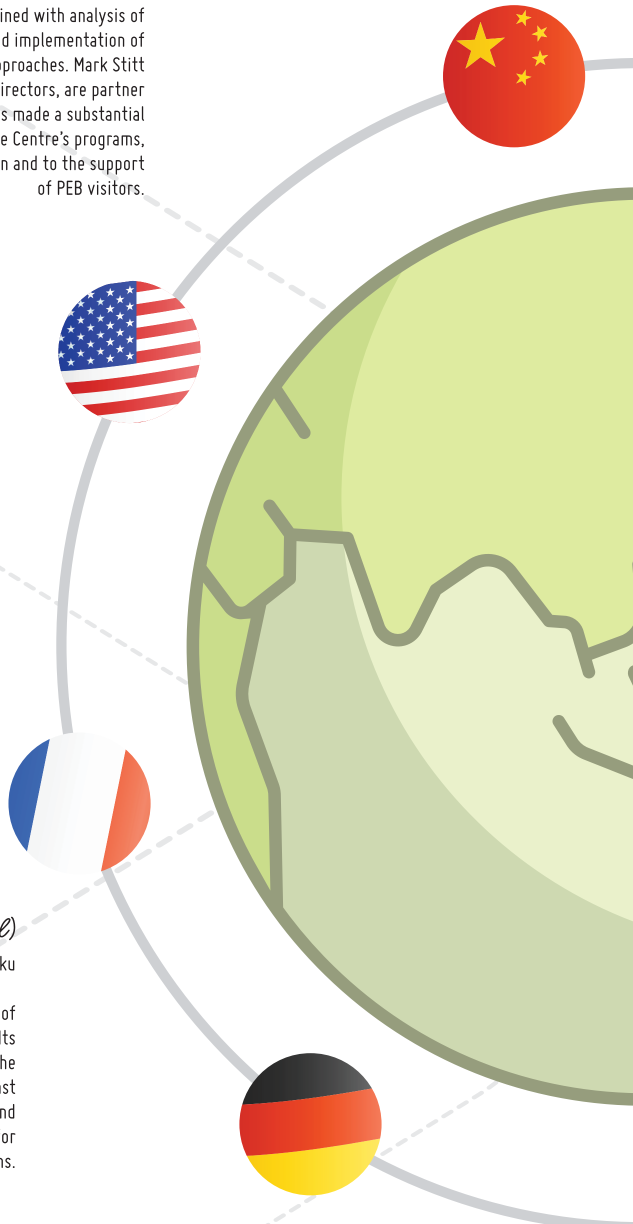
Steve investigates the links between ion and water transport in plants and, as Wine Industry Chair of Viticulture at the University of Adelaide, he applies his research to grapevine root physiology. Steve is a Fellow of the Australian Academy of Science.

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.

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 2017, PEB partnerships resulted in a number of significant research publications in top journals.

Regulation of chloroplast biogenesis
[PEB-UWA, Umeå Plant Science Centre UPSC]

The chloroplast is the location of photosynthesis, where plant cells synthesise the sugar essential for growth. Despite the chloroplast's importance, regulation of this organelle's construction is only vaguely understood.

A collaboration between the Umeå Plant Science Centre (UPSC) and PEB has enabled the characterisation of chloroplast biogenesis. UPSC's development of a unique cell culture allowing synchronous chloroplast biogenesis to be induced via illumination allowed PEB researchers to carry out a detailed time course of expression of both nuclear and chloroplast genes throughout the organelle's biogenesis.

Two distinct phases of chloroplast biogenesis were characterised, the first of which is triggered by light. This leads to rapid changes in gene expression and the slower construction of the gene expression machinery within the chloroplast. Once complete, a second phase is triggered in which photosynthetic machinery is rapidly assembled to create a functional chloroplast, and this is associated with its transport to the cell cortex where it becomes photosynthetically competent.

This research provides insight into how we might control photosynthetic development in plants in the future.

Dubreuil C, Jin X, Barajas-López JD, Hewitt TH, Tanz S, Dobrenel T, Schröder W, Hanson J, Pesquet E, Grönlund A, Small ID, Strand A (2017) Establishment of photosynthesis is controlled by two distinct regulatory phases. PLANT PHYSIOLOGY 176(2):1199-214

Improving phosphate uptake in crops
[PEB-LTU, Zhejiang University]

Without the application of phosphate fertiliser, crop yields in Australia would decrease by 50% or more. Yet the high cost of phosphate fertiliser, coupled with inefficiency of uptake by target crops leading to much phosphate being lost as a waterways pollution, means that optimising phosphate uptake and use by crop plants holds significant commercial, environmental and community value.

While the molecular components that regulate phosphate uptake in plants are known, the regulation of these regulators and how they interact with other major growth promoting pathways in plants remains elusive. Arabidopsis has proven a powerful model plant for the study of such regulatory pathways, however it is recognised that in major crop plants, such as rice and wheat these regulatory mechanisms may differ.

Studying rice, researchers at PEB's La Trobe University node together with the College of Life Sciences, Zhejiang University (ZJU), used a variety of approaches from cell biology and biochemistry to genetics, genomics and the latest gene editing technology to demonstrate that the master regulator of phosphate uptake in plants, PHO2, was regulated by the REDOX system in cells. Further, this REDOX regulation was essential for PHO2 to maintain phosphate homeostasis.

Only through collaboration between PEB and ZJU was the complementary and diverse expertise and the combined resources required to carry out this research in a crop plant achievable, in order to uncover this novel form of regulation.

These findings provide alternative approaches to modulating PHO2 activity, either chemically or genetically, in order to optimise phosphate uptake in crop plants.

Ying Y, Yue W, Wang S, Li S, Wang M, Zhao Y, Wang C, Mao C, Whelan J, Shou H (2017). Two h-type thioredoxins interact with the E2 ubiquitin conjugase PHO2 to fine-tune phosphate homeostasis in rice. PLANT PHYSIOLOGY 173(1): 812-24

An essential protein for mtDNA repair
[PEB-UWA, Ghent University]

Mitochondrial DNA (mtDNA) is important for energy production in plants and must constantly be maintained as mutations can lead to decreased plant growth. Homologous recombination is one mechanism used to repair the mtDNA and keep the organelle's genome healthy. Despite this, the proteins associated with this process have not been full elucidated.

In collaboration with Ghent University, PEB researchers have identified SWIB5 as the first gene required for homologous recombination of plant mtDNA in vivo.

Ghent University PhD student Jonas Blomme worked in partnership with PEB-UWA researchers to access both the assays and techniques required to measure the functional impact of SWIB5 mutations. Together, the researchers discovered that SWIB5 loss-of-function mutants display changes in mitochondrial gene expression and poor plant growth caused by mitochondrial function changes.

The protein was found to be needed for mtDNA repair via homologous recombination and plays a role in influencing mtDNA architecture. The study provides new insight into DNA repair mechanisms in the mitochondria and suggests a link between organelle function and plant development.

Blomme J, Van Aken O, Van Leene J, Jégu T, De Rycke RM, De Bruyne M, Vercruysse J, Nolf J, Van Daele T, De Milde L, Vermeersch M, Colas des Francs-Small C, De Jaeger G, Benhamed M, Millar AH, Inzé D, Gonzalez N (2017) The Mitochondrial DNA-Associated Protein SWIB5 Influences mtDNA Architecture and Homologous Recombination. PLANT CELL 29(5): 1137-1156.

" Our partners inject unique ideas and capacities. Collaboration can only value-add to our research. "


THE PLANT ENERGY SYSTEM IS THE
LARGEST SET OF BIOCHEMICAL
REACTIONS ON EARTH. TOGETHER
WE CAN UNDERSTAND AND
ENHANCE PLANT ENERGY
EFFICIENCY FOR OUR 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.

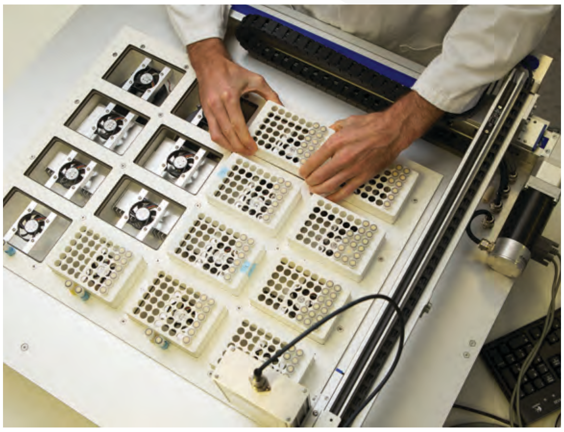
The Solution

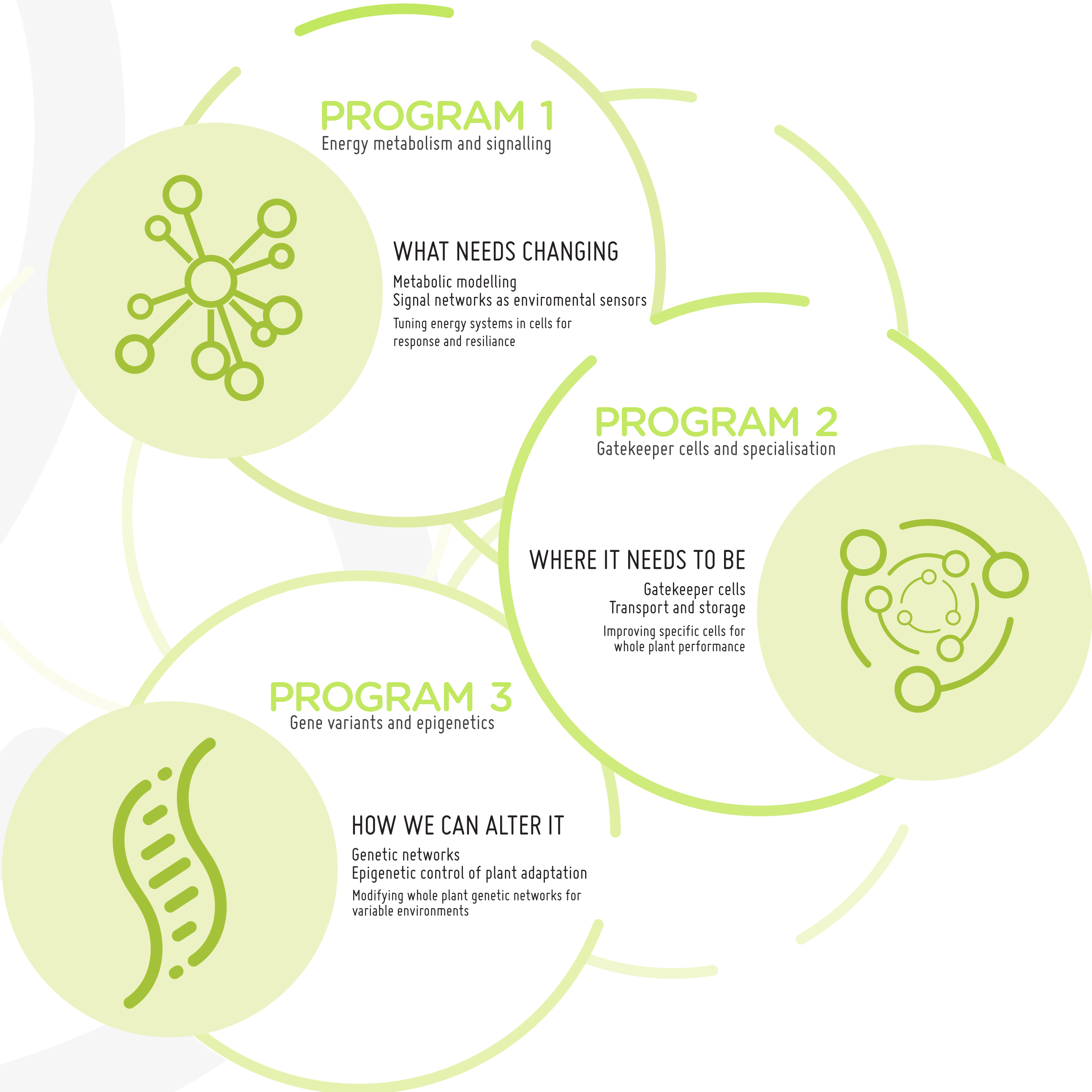
Many of these partial losses occur due to limitations and reduced efficiency in interconnected metabolic processes. Thus, small efficiency gains in the multitude of processes beyond carbon capture, but before harvest, can combine to have a magnified benefit on yield.

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.





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 1

ENERGY METABOLISM AND SIGNALLING

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 Katharina Belt completed her Masters studies in Germany before joining PEB in 2014 to undertake PhD studies at UWA. Her research has focused on plant stress signalling and responses to pathogens and environmental factors by studying salicylic acid-induced stress. Her discovery that Succinate Dehydrogenase (SDH), one of the five components of the mitochondrial electron transport chain plays an important role in triggering stress signalling in plants through the generation of reactive oxygen species (ROS) lead to a first author publication in *Plant Physiology* in 2017.

"A better understanding of how plants deal with stress could open up new opportunities to develop stronger plants for agriculture in the future" she said.

Having completed her PhD in 2017 Katharina has begun a postdoctoral Fellowship at CSIRO Agriculture and Food. *"A big part of PEB's success is due to the great diversity of the team. Putting many ideas and thoughts together leads to creativity and efficiency."*

Personal Success

Dr Andrew Scafaro joined PEB's ANU node as a Postdoctoral Fellow in 2015. His research has focused heavily on ways to improve the heat stress tolerance of crops. In 2016, Andrew took up a position with Bayer CropScience Innovation Centre in Ghent, Belgium. He has remained affiliated with PEB as a Visiting Fellow, authoring two 2017 papers with the Centre.

Andrew describes these publications as "topically diverse" - one relates to modelling the acclimation of photosynthesis in temperate and tropical tree species (*Global Change Biology* 2017), the other describes a novel method for high throughput and whole plant screening of respiration (*Plant Methods* 2017). This method is now being utilised by PEB to phenotype the respiration of a wide panel of wheat cultivars for energy efficiency.

Andrew considers his biggest success of 2017, however, as the birth of his first child.

"I love being a scientist, because there is no better feeling than discovering something new" he said.

"I hope my work can provide a tangible contribution to food security in a world with a more extreme climate".

Research Highlight
The cost of protein turnover

One of the most energy intensive life processes for a plant is protein turnover. Within a cell, proteins are constantly being synthesised and degraded in this process. An understanding of the variables contributing to protein degradation could allow the selection or modification of plants to create longer lasting proteins, thus reducing energy expenditure to manufacture replacement proteins.

PEB researchers have determined the lifespans of over 1,000 leaf proteins and how much energy a plant needs to spend to maintain protein levels and functionality. Proteins were found to last from just a few hours to several months.

Features of long lasting proteins were identified and can be utilised to engineer more robust, less energy expensive proteins.

Decreasing the cost of one of the most energy intensive processes of a plant cell will lead to more energy efficient crops in the future.

Li L, Nelson CJ, Trösch J, Castleden I, Huang S, Millar AH (2017) Protein Degradation Rate in *Arabidopsis thaliana* Leaf Growth and Development. PLANT CELL 29(2):207-228.

Research Highlight
Rapid recovery from light-stress

Plants have evolved over millennia to endure periods of drought, blistering sun and heat, among other environmental stresses. In response to environmental stresses specific mRNAs are produced, resulting in crops yielding less grain as resources are diverted towards survival.

When these mRNAs are degraded the plant returns to a pre-stress state. However, if they are degraded too slowly the defences are maintained long after the stress. Thus, quick stress recovery can lead to increased biomass as less energy is spent maintaining unnecessary defences.

PEB researchers have investigated the mRNA levels in plants after exposure to light stress and found that some mRNAs rapidly recover from stress in a process called Rapid Recovery Gene Downregulation (RRGD). Further research into RRGD can increase the transition speed from defence to growth and help crops thrive in varied environmental conditions.

As environmental stressors are set to become progressively more common, crops that adapt quickly to changing weather conditions will become of increasingly importance to feed the growing population.

Crisp PA, Ganguly D, Smith AB, Murray KD, Estavillo GM, Searle IR, Ford E, Bogdanović O, Lister R, Borevitz JO, Eichten SR, Pogson BJ (2017) Rapid recovery gene downregulation during excess-light stress and recovery in Arabidopsis. PLANT CELL 29(8):1836-1863

PROGRAM II

GATEKEEPER CELLS AND SPECIALISATION

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.

- **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.

  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. This multi-faceted approach aims to avoid the trade-offs in phosphate responses that impact plant growth.

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

Dr Sunita Ramesh is working to better understand the role of ion channels and transporters in abiotic stress tolerance in plants. As a Senior Research Associate at PEB's University of Adelaide node, her current research is focused on dissecting out the role of y aminobutyric acid (GABA) signalling in acid and alkaline stress tolerance.

Originally from Bangalore, India, Sunita's desire to understand *“how organisms live, what made them tick and how the different processes in a cell are coordinated”* drove her to pursue a career in science.

Her interest in how sessile plants have evolved adaptations to counter abiotic and biotic stress has resulted in her authoring a number of high-impact publications (including *Plant Cell 2018, Cellular and Molecular Life Sciences 2017* and *Nature Communications 2015*). Sunita was awarded the Women's Research Excellence Award by the University of Adelaide in 2017 for her efforts.

“Working in PEB with brilliant, inquisitive and fun-loving colleagues has made my research thoroughly enjoyable” she said. *“I attribute part of my success to the fantastic research environment within PEB, a collaborative atmosphere among researchers and excellent support and mentorship”.*

Personal Success

Dr Caitlin Byrt and **Dr Stefanie Wege** are the inaugural recipients of the Rana Munns PEB Early Career Research Award, established in 2017 to facilitate the development of independence in early career researchers and to support gender equity. The award supports their research into *Improving yield stability with energy efficient root solute transport traits*.

The award has enabled the recruitment and research training of postgraduate student **Muhammad Khairul Hisyam Ahmad Sohaimi,** allowing Caitlin and Stefanie to advance their independent research and mentoring skills.

"Through this opportunity to work together in supervising a PhD student to address an outstanding plant biology mystery - barley's missing exodermal barrier - we expect this project will translate into high impact publications and future funding opportunities" said Stefanie.

"By co-supervising Hisyam and advancing this project together, we will learn complementary skills from each other and profit from combined knowledge" said Caitlin.

Caitlin contributes expertise in cereal research, Na^+ transport, barley growth and cell wall biology while Stefanie lends extensive knowledge of membrane transport functions, dynamic nutrient interaction and expert skills in advanced microscopy to the project.

"These complementary skills will enable us to gain new insights into how roots coordinate cell wall and membrane transport traits".

Research Highlight
Reducing phosphate needs

Improving fertiliser use by crops, in particular phosphorus use, is key to sustainable agriculture. Rock phosphate is a finite, non-renewable resource, with high-grade and high-quality reserves gradually being exhausted.

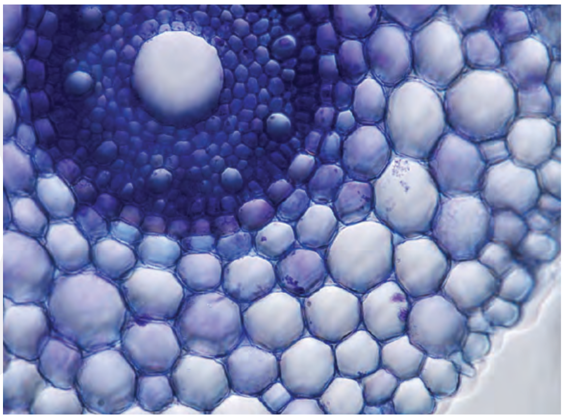
To date, attempts to improve plant phosphate uptake through genetic manipulation of regulatory proteins have by and large resulted in smaller plants and reduced yield.

Through a data mining approach, PEB researchers were able to predict plant genes that respond to changes in phosphate supply in a root-cell specific manner. By focusing on gatekeeper cells within the root known to control nutrient flux, and specifically targeting regulators of phosphate uptake, the team was able to circumvent the negative effects traditionally seen in efforts to increase plant phosphate uptake.

The researchers found that reducing the expression of the targeted genes resulted in better growth of plants exposed to a wide range of phosphate levels.

The findings exemplify that a targeted approach can successfully overcome critical hurdles in boosting plant phosphate-use efficiency. The research could lead to decreased fertiliser requirements, due to more efficient nutrient acquisition, and further, reduce fertiliser run-off and fresh water pollution.

Linn J, Ren M, Berkowitz O, Ding W, Van Der Merwe MJ, Whelan J, Jost R (2017) Root cell-specific regulators of phosphate-dependent growth. PLANT PHYSIOLOGY 174(3): 1969-89.



Research Highlight
A calcium-driven immune strategy in plants

Higher plants have evolved sophisticated gatekeeper-style channels called plasmodesmata (PDs), which modulate cell-to-cell communication. These microscopic channels create connections between cells and can facilitate the diffusion of metabolites, hormones, small RNAs and proteins responsible for controlling cellular processes and whole plant physiology.

PD pathways can be hijacked by pathogens, including bacteria, viruses and fungi, to aid their spread and this can lead to tissue damage, reduced crop yield and plant death. Previous studies suggested that an increase in cytosolic calcium (Ca^{2+}) concentration could close PD, but the mechanism behind this remained unclear. In collaboration with the John Innes Centre and RIKEN, PEB researchers identified the first molecular Ca^{2+} sensor that localises to the PD and reduces PD flux, improving a plant's tolerance to bacterial pathogens. The findings suggest a Ca^{2+} regulatory pathway occurs at PDs which contributes to a direct remodelling of the PD size exclusion limit during the mounting of a plant's immune defences.

This research expands our knowledge of plant immunity and suggests a new strategy that could be employed to improve plant performance and the suitability of Australian crops.

Xu B, Cheval C, Laohavisit A, Hocking B, Chiasson D, Olsson TSG, Shirasu K, Faulkner C, Gilliham M (2017) A calmodulin-like protein regulates plasmodesmal closure during bacterial immune responses. NEW PHYTOLOGIST 215(1):77-84.

PROGRAM III

GENE VARIANTS AND EPIGENETICS

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 sensitive environmental observation, at both the individual and population levels.

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 how this couples with phenomic variation in natural populations of plants using genome wide association mapping, and through (epi)genome profiling in a variety of environments.

- **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.

- **Uncovering the role of epigenetics through multigenerational responses to environments.**
  It has been proposed that epigenetic modifications in plant genomes can change rapidly, in an apparently stochastic manner, and may transmit to subsequent generations of plants. There is also evidence that the plant epigenome undergoes specific changes in response to challenging environmental conditions.

  We have investigated the role of epigenetic plasticity in plant multigenerational responses to challenging environments. Understanding the extent to which multigenerational epigenomic variability influences genetic and phenotypic variation under challenging conditions will determine the extent to which control of these process can generate stable and resilient plants in the future.

  We observe changes in the epigenome in response to a range of stress conditions. Detailed examination is indicating that these changes can, at least partially, be transmitted through mitosis, but not passed onto subsequent generations.

- **Developing new tools for precision editing of the epigenome to engineer plant energy efficiency.**
  To further study and manipulate genes and cellular signalling pathways the Centre aims to specifically induce (epi)alleles in plants. Novel approaches to precision editing of epigenetic patterns and new and powerful genome editing technologies will allow the transfer of advantageous genetic variants.

  By further modification of new genome editing systems we will develop innovative targeted epigenome engineering tools to deliberately reprogram the epigenome. We are currently seeing these approaches working with genomic specificity in cell lines.

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 Brendan Kidd joined PEB in 2017, bringing expertise in the machinery controlling plant transcription. A 2017 recipient of a prestigious CSIRO Synthetic Biology Future Science Fellowship, which aims to stimulate synthetic biology research in Australia, Brendan will undertake a three year project in the laboratory of Prof. Ryan Lister.

Brendan's focus is on designing better ways to control plant functions via novel synthetic regulatory elements, in the hopes of designing more precise control mechanisms for use in plant research.

"We're focusing on creating stronger activators and repressors to produce gene switches, known as logic gates. Genetic logic gates allow control of pathways and regulatory mechanisms, making biology easier to program" he said. *"We hope to make the first steps towards complex regulatory designs for plant pathways that enable greater plant production with fewer resources and in challenging climates."*

Personal Success

Dr Norman Warthmann joined the group of Justin Borevitz as a Research Fellow in 2012, officially becoming part of PEB in 2014. His research has focused on characterising genetic variation within plant species.

"At the heart I am a developmental biologist. Different genotypes behave differently in similar environments and this can be studied with genetics and molecular biology, which has become ever more powerful."

"We can now compare entire genomes from hundreds of individuals and that's very exiting!"

Norman recently moved on from PEB to a position with the United Nations. He will work with researchers from around the world to assist them in unleashing the tools of modern genetics to tackle plant breeding challenges.

"I got to where I am by serendipity, through mentors who believe in me, who opened doors, who led by example but, mostly, allowed me to pursue what I wanted. With this support, work did not feel like work, but like a world full of opportunities."

Research Highlight
Plant DNA methylome impervious to drought stress

DNA methylation is believed to hold the potential to transmit a memory of certain stressful events, such as drought, high-light and frost, to enhance plant resilience. PEB researchers have, however, discovered that methylation of the plant epigenome is stable under trans-generational drought stress.

Through profiling of changes to DNA methylation occurring under drought conditions the researchers discovered that, while there was a modest change to a plant's methylome within a generation, these were not linked to changes in gene expression.

When multiple generations of drought stress was performed, while drought associated epi-alleles could be detected, there was no correlation with drought resistance.

Overall, it was found that variation in the DNA methylome, the majority of which is unrelated to the change in environmental conditions, might instead be attributed to random variation.

The research shows that drought-stress is not associated with any functional changes in the DNA methylome, necessitating a re-evaluation of the function of plant epigenetic processes towards stress tolerance.

Ganguly D, Crisp PA, Eichten SR, Pogson BJ (2017) The Arabidopsis DNA methylome is stable under transgenerational drought stress. PLANT PHYSIOLOGY 175(4): 1893-912.

Research Highlight
Novel estimator of genetic similarity

Modern genomics techniques generate overwhelming quantities of data. Extracting population genetic variation demands computationally efficient methods to determine genetic relatedness between individuals in an unbiased manner.

PEB researchers described an assembly-, and alignment-free estimator of genetic similarity, that combines a probabilistic data structure with a novel metric, to efficiently calculate similarity between sample genomes.

Such rapid estimation of genetic relatedness directly from sequencing data allows researchers to verify that individuals belong to the correct genetic lineage before conclusions are drawn using mislabelled, or misidentified samples.

The use of such algorithms will accelerate analyses of natural genetic variation to unlock knowledge of phenotypic and genotypic diversity that can be exploited for future-proofing of our ecosystems and agricultural production, even in species where no genetic resources are available.

Murray KD, Webers C, Ong CS, Borevitz J, Warthmann N (2017) kWIP: The k-mer weighted inner product, a *de novo* estimator of genetic similarity. PLOS COMPUTATIONAL BIOLOGY 13(9): e1005727.

IT'S NOT GOOD ENOUGH TO JUST DO EXCELLENT RESEARCH. TO HAVE IMPACT WE DO IT WITH AN EYE TO ITS APPLICATION AND RELEVANCE TO SOCIETY.

RESEARCH IMPACT

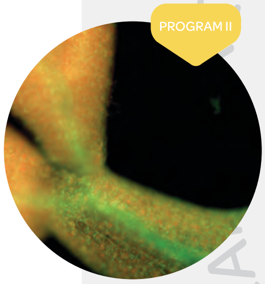
TRANSLATION TO RESEARCH APPLICATION

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.

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.

PROGRAM I

Improving Drought Tolerance in Wheat

According to a 2016 Climate Council report, the expected increase in frequency and severity of drought stress in Australia over the next few decades will cost the economy $5.5 billion dollars annually. Engineering next-generation drought-proof crops is therefore of utmost importance.

Through a Grains Research and Development Corporation (GRDC)-funded project, PEB is building on its previous discovery of PAP, a drought stress signal in plant cells, to develop drought-tolerant wheat lines with altered levels of PAP. Several lines have shown no yield penalty and better yield potential in field trials performed across two seasons. In light of this promising field data, these lines are now being extensively tested for their drought tolerance potentials at four sites across Australia under rainfed (water limited) and irrigated conditions.

A concurrent project, jointly funded by PEB and a Canberra-based venture capital fund, is developing novel agrochemicals capable of selectively activating drought stress responses in plant cells when applied onto leaves; thereby pre-acclimating plants prior to onset of drought stress without the need for genetic modification or breeding.

PROGRAM II

Mapping Epigenomes

Technologies developed in model plants can be applied to other organisms. The application of the Centre's advances in epigenome analysis has not been limited to plant and agricultural research.

Collaborations with the Salk Institute for Biological Studies as well as affiliated Fellows in PEB has demonstrated that epigenetic mapping technologies and the study of *de novo* methylation patterns can be applied to the generation of complete epigenome maps to better understand the evolution of methylation patterns in vertebrate embryogenesis, retinal photoreceptors and brain neurons, as well as the genome evolution of polyploid animals and plants. Unlocking the secrets of plant biology may thus have far reaching benefits that can be translated to other fields of research, including human health and development, and animal evolution.

PROGRAM III

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 growth regions or 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 model research plants such as *Arabidopsis* and *Brachypodium* but for crop plants, such as wheat. In 2017 we were awarded funding to install larger grow capsule climate containers to grow larger plants under simulated field conditions with high light and Phenotyping capacity. This will allow us to perform climate adaptation experiments in crops and foundation species.

INTERNATIONAL WHEAT YIELD PARTNERSHIP PROJECT

Through a novel approach that combines cutting edge molecular techniques with traditional breeding, and a collaborative effort that draws on expertise across Centre nodes and from international partners, PEB is helping to raise the genetic yield potential of wheat in order to address global food security.

" Working together to improve wheat yield through optimised energy efficiency "

Globally, wheat is one of the most important staple crops, providing a fifth of the daily calories in human diets. According to The Food and Agriculture Organisation of the United Nations, global crop yields must double by 2050 to meet future food security needs.

To address this need Agriculture Ministers of the G20 nations established the International Wheat Yield Partnership (IWYP), a unique, international funding initiative to co-ordinate worldwide wheat research efforts.

Commencing in 2016, The PEB-led IWYP project *Improving Wheat Yield By Optimising Energy Use Efficiency* is employing innovative molecular techniques combined with traditional breeding approaches to exploit the energy systems of wheat plants to dramatically improve their yield.

The team from PEB, together with project partners including the International Maize and Wheat Improvement Centre (CIMMYT), in Mexico, are combining genetics, gene expression and growth studies with the high throughput analysis of photosynthesis, respiration, proteomics and metabolomics in order to screen elite wheat germplasm from field trials in Australia and Mexico and identify new opportunities for wheat improvement through selective breeding for energy use efficiency.

The team combines the expertise of Chief Investigators Pogson, Borevitz, Atkin, Millar and Gilliham and centre research fellow Dr Nicolas Taylor, with our collaborators Dr Matthew Reynolds (CIMMYT) and Prof. Robert Furbank (ANU).

Project progress

Field trials completed in 2016 and 2017 have shown a more than two-fold heritable variation in respiratory rates of flag leaves in the field across high yielding wheat genotype panels. Analysis of metabolite and protein contents has begun, and already, new discoveries linking specific metabolic processes with growth, yield and respiration rates have been made.

We are set to provide new targets for assessing energy use efficiency in wheat in the near future.

The project ultimately aims to enable breeding of new wheat varieties with optimised levels of respiration and photosynthesis, sugars and organic and amino acids for increased growth and biomass with the potential for increased grain yield.

People and technology

The project Improving Wheat Yield By Optimising Energy Use Efficiency is leveraging expertise and technology from across PEB's University nodes and our partners to achieve a common goal of improving energy use efficiency in wheat for greater yield.

Project Partners

International Maize and Wheat Improvement Centre (CIMMYT)
Field trials, plant physiology and sample collection.

Photon Systems Instruments (PSI)
Software and equipment development for next-generation improvements to phenotyping in the lab and field.

Astec-Global Ltd
Co-development of optimised sample trays for high throughput respiration work.

ARC Centre of Excellence for Translational Photosynthesis
Collaborative research on hyperspectral imaging to assess energy traits in the lab and field.

Grains Research and Development Corporation (GRDC)
Primary project funder.

Australian National University

Dr Pip Wilson is the Project Manager, ensuring reporting and organisation of milestones as well as overseeing the logistics and wheat genetics of the project.

Dr Andrew Bowerman has developed robotics for sample handling, and a range of data analysis pipelines for integration and interpretation of project data.

Dr Reshmi Gaju is a plant physiologist and manages the field campaigns with CIMMYT, Mexico and also in Australia.

Dr Darren Cullerne has developed and managed the databases for sample and data management and aspects of computational analysis and data quality control.

University of Western Australia

Dr Elke Ströher manages Metabolomics and Proteomics platforms for the project.

Ms Ricarda Fenske manages Metabolomics and Proteomics platforms for the project.

Dr Ting Tang has worked on project sample preparation and the analysis of metabolite and peptide measurements.

University of Adelaide

Dr Allison Pearson has developed quantitative trait loci and gene identification and mapping of energy traits in doubled haploid wheat populations.

MULTIDISCIPLINARY RESEARCH THROUGH COLLABORATION

Multidisciplinary research brings together unique skills and perspectives in order to solve problems. PEB extends its research outcomes through multidisciplinary research in two ways: the Centre hosts a number of Affiliate researchers with distinct expertise and collaborates with them in their research; and PEB engages in national and international collaborative projects with individuals and organisations from different disciplines.

RESEARCH WITH AFFILIATED SCIENTISTS

Protecting plant pollinators

Collaboration with CRC for Honey Bee Products

Honey bee health is in decline globally, mainly due to spreading parasites, agricultural pesticide exposure and beekeeping practices and loss of habitat. Consequently, tools of integrative beekeeping practices are needed as a matter of urgency to safeguard our bees in Australia.

The Cooperative Research Centre for Honey Bee Products (CRC-HBP), which was established in 2017, will work towards future-proofing this precious pollinator. Drawing on proteomic and genomic expertise within PEB, the CRC-HBP is working to identify molecular markers of disease resistance to implement into bee breeding programs, and is studying the genomics of honey bee pathogens to better mitigate disease.

Biomedical applications from plant evolution

Collaboration with Dr Joshua Mylne

PEB's Affiliate Researcher Joshua Mylne leads research examining the genetic events that evolve new plant proteins, with particular focus on those with pharmaceutical applications.

Dr Mylne collaborates with Centre staff and combines the discipline of plant biology with biomedical research and biochemistry, provides fundamental new knowledge about protein evolution and opportunities to engineer plants to produce valuable molecules.

Computational Biology for Sustainable Agriculture

Collaboration with Dr Laura Boykin and the Cassava Virus Action Project

The Boykin lab is working towards increasing crop yields for smallholder farmers in east Africa by utilizing genomics, phylogenetics and supercomputing. They focus their efforts on both the vectors and viruses that are devastating staple crops such as cassava and beans in many developing countries. Whiteflies (*Bemisia tabaci*) are the focus their research because they transmit plant viruses and are a major threat to food security globally.

They use genomics, phylogenetics and supercomputing to characterise both the whiteflies and the devastating viruses. Their ultimate goal is to provide species information to breeders and farmer's so they ensure their staple crops are resistant to the correct species circulating in their area.

Sharing laboratory and computational resources and expertise enable both the Boykin Lab and PEB to fulfil their complementary goals in food security.

MULTIDISCIPLINARY PROJECTS

Connecting research databases to aid new discoveries

Collaboration with Australian National Data Service and Librarians

With the support of the Australian National Data Service (ANDS), a number of valuable research databases from across Australia, including four from PEB, have been integrated into a single web portal, Agriconnect (agriconnect.latrobe.edu.au). Agriconnect makes connections between genomic, proteomic and phenomic data from more than 14 plant species, including Arabidopsis, banana, barley, canola, maize/corn, mungbean, potato, rice, sorghum, soybean, tomato, wheat and wine grape.

This tool enables discovery-based research by drawing novel links between genotype and phenotype and ultimately aims to improve the translation of knowledge between different plant species, accelerating agricultural applications. The linking of these databases is drawing on the combined expertise of PEB scientists, Librarians, ANDS Informaticians.

Defining a key element in the fight-or-flight response of animals

Collaboration with University of Western Australia, Harry Perkins Institute of Medical Research and Victor Chang Cardiac Research Institute

The fight-or-flight response is a vital physiological reaction that occurs in response to a perceived harmful event, attack, or threat to survival in animals. The nervous system drives this through activation of signalling pathways that result in responses in the heart which increase the intracellular calcium level and contractile force of the heart muscle.

The Cav1.2 protein is the pore forming and ion conducting subunit of the cardiac L-type Ca^{2+} channel and the main route for calcium influx into cardiac myocytes. In collaboration with medical researchers and physiologists, PEB scientists used mass spectrometry to help evidence that serine 1458 in the human cardiac Cav1.2 channel is a target for phosphorylation, leading to its activation. In so doing, this collaborative, multidisciplinary research has opened up a new opportunity for targeted regulation of the fight-or-flight response, and resulted in a *Scientific Reports*, 2017 publication.

Engineering plant phenomic facilities

Collaboration with PSI, LTU School of Engineering and Mathematical Sciences and ANU College of Engineering and Computer Sciences

Collaborations between PEB researchers at LTU and ANU, centre partner organisation Photon Systems Instruments (PSI), and engineers from the School of Engineering and Mathematics Sciences at LTU and the College of Engineering and Computer Sciences at ANU, are resulting in the design and construction of new phenotyping platforms within plant growth chambers, mobile containers and rooms. Based on precise thermal control, LED lights and image analysis systems, the facilities will track plant growth and development. These collaborations aim to form an advanced, energy efficient product through the combined expertise of plant science researchers and experts in both lighting systems and image analysis. The result will be integrated products with wide applications for adoption by plant science research organisations.

Factoring plants into climate modelling

Collaboration with multiple organisations

Through a multi-organisation collaboration funded by the Department of Energy (DoE) and National Science Foundation (NSF) in the USA, and in collaboration with the Centre for Ecology & Hydrology in the UK, PEB-ANU researchers are contributing to evidence-based climate modelling for the future.

Accurate prediction of carbon flow between plants and the atmosphere, of which plant respiration is a major source of carbon released, is central to climate models for the prediction of future global warming. In the most comprehensive study of plant respiration rates and their responses to temperature ever conducted the respiration rates of vegetation at 100 remote sites around the world, representing seven different types of plant habitat, were examined in this collaboration.

A new equation that describes global patterns in plant respiration and its temperature dependence, both now and into the future, has recently been incorporated into global climate models to account for acclimation responses of plant respiration.

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

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.

The **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 tens of thousands since its inception, VPC serves as a fantastic platform for dialogue between our scientists and the community and is a highly effective educational tool. The Centre continues its development and use of this exciting resource.

Outreach Highlight
VPC during National Science Week 2017

PEB had a huge impact during 2017 National Science Week, exhibiting at major science festivals in WA, SA, ACT and Victoria and connecting with over 4,000 members of the public.

Custom-created Virtual Plant Cell experiences, *VPC: Protein Turnover, VPC: Surviving Salt* and *VPC: Phosphate Focus* showcased our local research endeavours and served as excellent platforms for informed dialogue with the community. Visitors fed back that they had found the experiences "very engaging" and that it had boosted their interests in plant biology.

It was awesome!
My daughter, aged only 2, is enthralled by the Virtual Plant Cell.
My kids loved having the opportunity to look through this technology.
It was very interesting, had lots of great info.
(Feedback on VPC from our National Science Week visitors)

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.

VPC, Plantarium, Bio-Bounce and Plant Powerstation were used by PEB throughout 2017 to engage the community in plant science.

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 2017. 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 2017. 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

Powerful Plants at Woodend Primary School

In his capacity as a 2017 South Australian Young Tall Poppy, PEB scientist Dr Jay Bose connected 125 year 6 and 7 students at Woodend Primary School with the power of plants and the importance of plant energy biology research.

As part of the school's "Future Earth" expo, bright young scientists got hands-on with setting up their own experiments to study the effect of salty soil on plant growth. They also explored how plants handle salt inside of their cells using the Virtual Plant Cell virtual reality experience.

"Talking about why plants grow slowly and die in salty soils, and how our research can help to overcome future food insecurity with these students was a very rewarding experience" said Jay.

Media

PEB recognises that the Australian media is an avenue to achieve broad community reach for the communication of our science. In 2017 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 2017 PEB achieved over 230 online, television and radio media commentaries, and continued the use of its established social media platforms to promote PEB science and educate the community through news from the Centre. PEB also launched its Virtual Plant Cell Facebook page to widely showcase this exciting, educational virtual reality experience.

Media Highlight

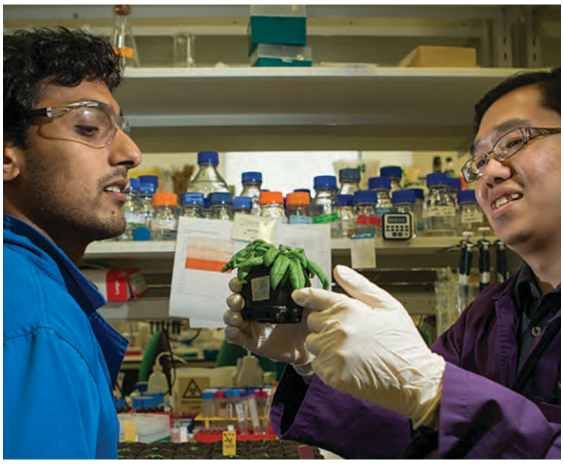
Lending plants a hand to survive drought

A team of PEB researchers at the Australian National University told the world of their exciting discovery of a cell signalling pathway which can help plants during drought stress.

The finding suggests a novel way in which plants can enhance their natural ability to conserve water by closing off pores on their leaves in order to help them better tolerate drought. Interestingly, the researchers found that chloroplasts, a part of plant cells better known for a role in photosynthesis, are actually key players in this process.

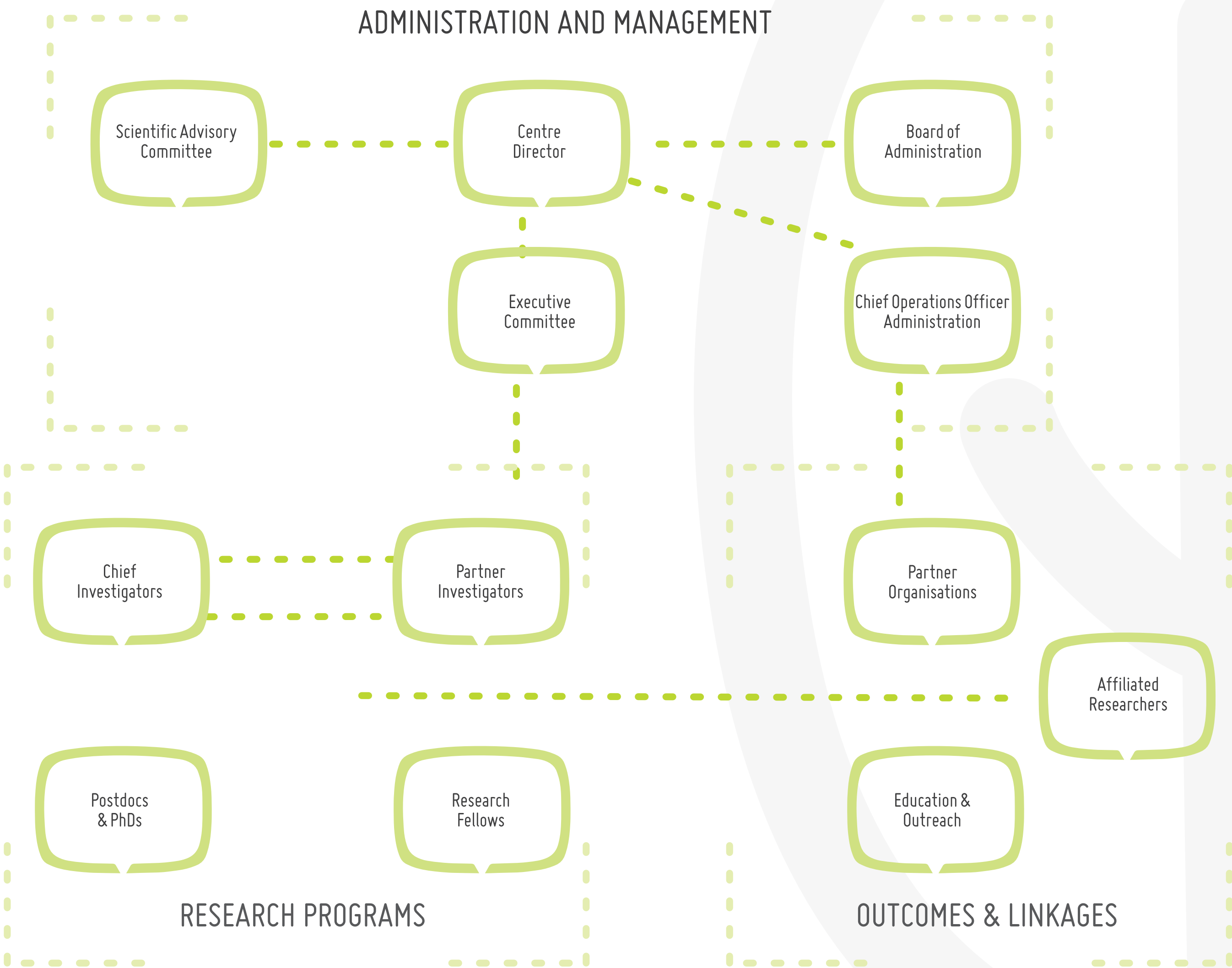
"If we can even alleviate drought stress a little it would have a significant impact on our farmers and the economy" Professor Barry Pogson said of the study.

The story circulated online, TV and radio media in Australia and around the world, making the headlines in Asia, South America and Africa. The research has been published in the journal *eLife.*



TACKLING THE PLANT ENERGY EFFICIENCY CHALLENGE REQUIRES A TEAM. THROUGH OUR COMBINED EFFORT AND EXPERTISE WE CAN CHANGE THE FUTURE.

PEOPLE



"The injection of new ideas, exciting expertise and novel ways of solving problems make for an ever-evolving Centre of Excellence"

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 91 PhD, Masters and Honours students enrolled during 2017, 14 of whom commenced and 10 who successfully completed in the year. PEB students claimed a number of awards and authored numerous publications in 2017.

Student Highlight

Yue (Julian) Qu has been investigating salinity tolerance mechanisms in soybean as a PhD student at PEB's University of Adelaide node. His work to functionally characterise *GmSALT3*, a salt tolerance gene in soybean, lead to a 2014 feature article in *The Plant Journal* and a *Frontiers of Plant Science* publication in 2017.

Originating from China, Yue came to Australia in pursuit of a career in biological sciences.

"Since I was a kid I've been fascinated by natural science, from a carpet of green grass to trees reaching for the sky".

"With age, I became interested in investigating the secrets behind nature - how plants can grow near the sea and how they can survive the heat and drought of a desert".

"My research has focused on how soybean plants handle salinity stress at physiological and molecular levels".

Yue was awarded an Australian Plant Phenomics Facility Postgraduate Internship Award in 2017 to investigate soybean phenotypes under drought and salt stress. His project has formed part of a valuable collaboration with the Chinese Agricultural Academy of Science.

Yue completed his PhD with commendation at the end of 2017 and will continue and expand his soybean research as a Research Fellow with PEB.

"I am fortunate to have a group of knowledgeable, accommodating, and passionate colleagues to help me on my research journey".

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. s for these scientists and their staff and students.

Affiliate Highlight

Dr Julia Grassl studies the effects of disease and nutrition on honey bee health. She is the Program Leader for the recently established Cooperative Research Centre for Honey Bee Products (CRC-HBP), running the Honey Bee Health Research Group, and is an Affiliate Researcher to PEB at the University of Western Australia. Julia oversees research that draws on the expertise and resources of both Centres.

Julia has previously worked with the Centre of Integrative Bee Research (CIBER) and as a postdoctoral researcher at PEB- UWA. Her expertise in quantitative proteomics and mass spectrometry has been applied to many research projects investigating social insects, plants, humans and other organisms.

Julia most recently published research describing how male bees fight sexually transmitted disease in the Journal of Proteome Research, 2017. The establishment of the seven million dollar CRC-HBP in 2017 will allow Julia to advance her work into honey bee health and immunity in partnership with industry, to provide real-world solutions.

"Honey bees, our essential pollinators, are under threat",

"The CRC has given me a great opportunity to work with the beekeeping industry and to translate the research we do into applied changes for the industry, the environment and how we perceive honey bees".

Her research into the effects of environmental stressors on honey bees, in order to safeguard these important pollinators through the application of molecular techniques, is made possible through her collaboration with PEB.

"PEB has provided me with access to great researchers, a wealth of knowledge and expertise as well as state of the art instrumentation that can really advance my research".

In turn, PEB benefits greatly from Julia's expertise, her recruitment of enthusiastic new students and her extension of the Centre's research.

Julia is also a proud role model, as a successful scientist, to her two young daughters.

AWARDS & RECOGNITIONS

Jayakumar	Bose	SA Young Tall Poppy Award	Australian Institute of Policy and Science
Caitlin	Byrt	South Australian Community Achievement Award in Agriculture	Awards Australia
Caitlin	Byrt	Science and Innovation Award for Young People in Agriculture, Fisheries and Forestry	Department of Agriculture and Water Resources Women in Innovation SA
Caitlin	Byrt	Winnovation Award	Australian Institute of Policy and Science
Kai	Chan	ACT Young Tall Poppy Award	Office of the ACT Chief Minister
Kai	Chan	2017 ACT Scientist of the Year	Australian Awards for University Teaching, Federal Department of Education and Training
Kai	Chan	National Citation for Outstanding Contribution to Student Learning	Australian Awards for University Teaching, Federal Department of Education and Training
Peter	Crisp	National Citation for Outstanding Contribution to Student Learning	Australian Awards for University Teaching, Federal Department of Education and Training
Diep	Ganguly	National Citation for Outstanding Contribution to Student Learning	Executive Dean, Faculty of Sciences, University of Adelaide
Matthew	Gilliham	Mid-Career Researcher of the Year	Australian Awards for University Teaching, Federal
Xin	Hou	National Citation for Outstanding Contribution to Student Learning	Department of Education and Training
Muhammad	Kamran	Plant Nutrition Trust Travel Scholarship	Plant Nutrition Trust
Harvey	Millar	2017 WA Scientist of the Year	Premier's Science Awards, Government of Western Australian
Monika	Murcha	WA Young Tall Poppy Award	Australian Institute of Policy and Science
Brendan	O'Leary	Rising Star Finalist	Faculty of Science, University of Western Australia
Su Yin	Phua	Associate Fellowship	Higher Education Academy
Su Yin	Phua	National Citation for Outstanding Contribution to Student Learning	Australian Awards for University Teaching, Federal Department of Education and Training
Barry	Pogson	National Citation for Outstanding Contribution to Student Learning	Australian Awards for University Teaching, Federal Department of Education and Training
Barry	Pogson	2017 Highly Cited Researcher	Clarivate Analytics
Sunita	Ramesh	Women's Research Excellence Award	University of Adelaide
Megan	Shelden	ECR International Travel Award	University of Adelaide
Megan	Shelden	Priority Partnership Grant	University of Adelaide
Ian	Small	2017 Highly Cited Researcher	Clarivate Analytics
Aaron	Smith	Director's Prize for Honours	Research School of Biology, Australian National University
Aaron	Smith	University Medal	Australian National University
Estee	Tee	Associate Fellowship	Higher Education Academy
Estee	Tee	Excellence in Tutoring or Demonstrating Award	Vice Chancellor's Awards for Excellence in Education, Australian National University
Estee	Tee	National Citation for Outstanding Contribution to Student Learning	Australian Awards for University Teaching, Federal Department of Education and Training
Stephanie	Watts-Williams	Edith Dornwell ECR Excellence, Order of Merit	Faculty of Sciences, University of Adelaide
Stephanie	Watts-Williams	Roger Hill Travel Award	Australian Soil and Plant Analysis Council
Stephanie	Watts-Williams	ECR International Travel Award	University of Adelaide

PEB's team of exceptional researchers excel not only in their science but in their related endeavours. For this they are routinely recognised, and in 2017 PEB scientists were the recipients of a range of prestigious awards and recognitions.

Scientist of the Year

2017 ACT Scientist of the Year, **Dr Kai Chan**, says a career in science is challenging, but is also highly rewarding. The Scientist if the Year award recognises the contribution that Kai has made to science and innovation, both nationally and worldwide.

Kai's research focuses on the effect of drought conditions on plants and the ways in which plants can sense drought stress. In 2016 he described the breakthrough identification of a novel stress sensor in plants, SAL1, in the journal *PNAS.*

The ACT Scientist of the Year Award also aims to inspire young people to consider a career in science and STEM more broadly. Kai looks forward to the outreach opportunities that come with his role as Scientist of the Year.

"I'm like many early career scientists, curious about the mysteries of life and passionate about what we do."

"An award like this is important for early career researchers because it celebrates our collective achievements. It helps us to pause and remind ourselves of the rewards of staying in science and working away."

In 2018 Kai will take up a prestigious Marie Curie Postdoctoral Fellowship that will give him the opportunity to travel to Belgium and Finland further promote the contribution Australian scientists are making worldwide.

A Winner for her Innovation

Dr Caitlin Byrt was recognised for her innovation by the receipt of not one, but two prestigious 2017 prizes. Caitlin was awarded the Australian Department of Agriculture and Water Resources (ABARES) *Science and Innovation Award for Young People in Agriculture, Fisheries and Forestry*. She was also the recipient of a *Winnovation Award*, celebrating women in innovation.

The ABARES awards recognise big ideas from young rural innovators that contribute to the success of Australia's agriculture sector. Caitlin will use this award to study the roots of wild relatives of barley crops to see what makes them highly tolerant to stress. These traits could then be crossed into modern crops, resulting in higher grain yields.

"Food security is something that really concerns me and always has done," Caitlin says.

"Improving global food security is a big challenge"

The Winnovation Awards aim to showcase South Australia's best female innovators. Caitlin received the Winnovation Award for Science in recognition of her work to improve global food security through the identification of wheat genes that contribute to salt tolerance. Caitlin developed tools that have been distributed to 18 countries around the world so that plant breeders and farmers can improve the salinity tolerance of their local wheat varieties.

Three Tall Poppies

PEB hosted three Australian Young Tall Poppies in 2017. **Dr Jayakumar (Jay) Bose** was named South Australian Tall Poppy, **Dr Kai Chan** an ACT Tall Poppy, and **Dr Monika Murcha** a Western Australian Tall Poppy.

The prestigious Tall Poppy awards are presented annually by the Australian Institute of Policy and Science (AIPS) in recognition of outstanding work as both a researcher and a science communicator.

Jay's research has focused on the discovery of salt-tolerant genes from naturally salt-loving plants. He aims to introduce these genes into traditional crops to increase food production in countries that suffer from saline soils. He is passionate about raising awareness of environmental problems affecting crops and creating a positive public dialogue about how plant science can help combat these challenges. He campaigned for science at Science Meets Parliament and has delivered community presentations on climate-proofing crops.

Monika, a PEB Affiliate Researcher at the University of Western Australia, is focused on developing super-efficient plants that can thrive with limited fertiliser and survive changing environments. Her focus, in particular is on regulation within plant mitochondria.

Monika's enthusiasm for science outreach has seen her run interactive science sessions with school students, and participate extensively in PEB's outreach program. She has also been helped to promote women in STEM, and in particular, encourage women to continue their science careers following maternity leave through networks such as Athena SWAN and Women in Science.

Kai's research into plant responses to drought lead to his discovery of a protein that can sense drought, effectively acting like an alarm to alert a plant upon sensing a water shortage. Kai is a passionate science communicator who has spoken extensively about his research through the AgCommunicators program and taken part in many public science outreach activities.

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 Elizabeth S. Dennis FAA FTSE
Division of Plant Industry and Distinguished Professor, UTS

Professor Dennis is one of the world's leading plant molecular biologists. She is a CSIRO Fellow whose plant research has led to tangible outcomes in Australian agriculture. Her research focuses on gene regulation, both genetic and epigenetic. As Chairman of the Multinational Arabidopsis Genome Project Prof. Dennis played a key role in mapping one of the first plant genomes.

Prof. Dennis's scientific excellence is acknowledged through numerous awards and distinctions, including election as a Fellow of the Australian Academy of Technological Sciences and Engineering; election as a Fellow of the Australian Academy of Science; the Lemberg Medal for distinguished contributions to biochemistry; the Pharmacia LKB/Biotechnology Medal of the Australian Biochemical Society for contributions to Biochemical Research and the inaugural Prime Minister's Prize for Science.

Emeritus Professor Margaret Clayton
School of Biological Sciences, Monash University

Emeritus Professor Clayton has previously held the positions of Head of the School of Biological Sciences, Deputy Dean of the Science Faculty and the Faculty's Associate Dean (Research) at Monash University. Her research career has been on the functional importance of phenolic compounds in brown algae, the reproductive biology of marine algae and molecular phylogeny of brown algae.

Em Prof Clayton was the ARC's Executive Director of Biological Sciences and Biotechnology from 2006 till 2009.

Professor Dale Sanders FRS
Sohn Innes Centre, Norwich Research Park.

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. Steve Thomas
Executive Manager - Commercial, Grain Research and Development Corporation (GRDC)

Dr Thomas is responsible for the GRDC's increased focus on partnerships with commercial enterprises and overseas research entities. As the previous Executive Manager of GRDC's Research Program portfolio he led the development and implementation of a long-term strategy for maximising the impact of research investment.

Dr Thomas has held numerous roles across the agricultural research sector, including Director level roles at the New South Wales Department of Primary Industries and research positions in plant molecular biology with the Australian Centre for Necrotrophic Fungal Pathogens and with the Carlsberg Research Laboratories in Copenhagen.

Professor Dr. Detlef Weigel FRS
Department of Molecular Biology, Max Planck Institute for Developmental Biology

Professor Weigel is a Director of the Max Planck Institute for Developmental Biology in Tübingen, Germany. His research focuses on mechanisms which are responsible for adaptive variation of plants, discovered through the interface of plant biology, developmental genetics and evolutionary genomics.

Prof. Weigel has received numerous honours for his contributions to plant and evolutionary biology, including the Otto Bayer Award (2010) and the State Research Prize Baden-Württemberg (2011). He is an elected member of the European Molecular Biology Organisation (EMBO), the German National Academy of Sciences, Leopoldina, the US National Academy of Sciences and the Royal Society of London.

UNIVERSITY OF WESTERN AUSTRALIA

Abzalov	Aygul	PhD Student
Agudelo Romero	Patricia	Affiliated Research Associate
Ali	Adnan	Masters Student
Andrews	Jessica	Masters Student
Baer	Boris	Affiliated ARC Future Fellow
Baer-Imhoof	Barbara	Affiliated Researcher, Outreach Officer
Barrington	Guy	Honours Student
Bates	Tiffane	Affiliated Bee Yard Manager
Belt	Katharina	PhD Student
Bernath-Levin	Kalia	Affiliated Research Associate
Bogdanovic	Ozren	Affiliated Researcher - DECRA
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
Chan	Chee Seng	Honours Student
Che Othman	Hafiz	PhD Student
Cincu	Emilia	Graduate Research Assistant
Colas des Francs-Small	Catherine	Research Associate
Corral	Maxime	PhD Student
De Mendoza	Alex	Research Fellow
Dorett	Sarah	Honours Student
Du	Xianwen	Masters Student
Duffy	Ciara	PhD Student
Duncan	Owen	Affiliated Postdoctoral Researcher
Farthing	Rosemarie	Laboratory Technician
Fenske	Ricarda	Research Officer
Fisher	Mark	PhD Student
Franklin	Amy	PhD Student
Ghifari	Abi	Honours Student
Gill-Hille	Mabel	Honours Student
Gopal Krishnan	Priya Darshini	Honours Student
Grassl	Julia	Affiliated Postdoctoral Research Associate
Gutmann	Bernard	Affiliated Researcher - DECRA
Haywood	Joel	Research Associate
Honkanen	Suvi	Research Associate/CSIRO Fellow - ECR
Hook	Rochelle	Administrative Officer
Hooper	Cornelia	Postdoctoral Researcher
Huang	Shaobai	Affiliated ARC Future Fellow
Huynh	Dang Sang	Masters Student
Ivanova	Aneta	Affiliated Research Associate
Karpievitch	Yuliya	Research Associate
Kerbler	Sandra	PhD Student
Khan	Adil	PhD Student
Kidd	Brendan	Research Associate/CSIRO Fellow
Kinene	Tonny	PhD Student
Kratz	Madlen	PhD Student
Lee	Alex	Postdoctoral Researcher
Li	Lei	Postdoctoral Researcher - ECR
Lister	Ryan	Chief Investigator
Maseva-shayawabaya	Audrey	Masters Student
Mcdowell	Rose	Masters Student
Melonek	Joanna	Research Fellow
Millar	Harvey	Director and Chief Investigator
Millman	Michael	PhD Student
Mohamed	Sufyaan	PhD Student
Moo	Teck Lim	Honours Student
Moss	Dylan	PhD Student
Muhamad Hafiz	Che Othman	PhD Student
Munns	Rana	Chief Investigator
Murcha	Monika	Affiliated ARC Future Fellow
Mylne	Joshua	Affiliated ARC Future Fellow
Oh	Glenda	Honours Student
O'Leary	Brendan	Affiliated Researcher - DECRA
Oliva	Marina	Postdoctoral Researcher - ECR
Palanivelu	Nithya	PhD Student
Pattrick	Cameron	Masters Student

Petereit	Akob	PhD Student
Pflueger	Christian	Postdoctoral Researcher - ECR
Poppe	Daniel	Research Associate - ECR
Price	Karina	Science Communications Officer
Pruzinska	Adriana	Affiliated Researcher - DECRA
Royan	Santana	PhD Student
Salih	Karzan	PhD Student
Schepis	David	Honours Student
Secco	David	Affiliated Researcher - DECRA
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
Tan	Dennis	PhD Student
Tang	Ting	Affiliated Graduate Research Assistant
Tang	Anqiang	PhD Student
Tang	Dave	Research Fellow - ECR
Tanz	Sandra	Affiliated Researcher - DECRA
Taylor	Nicolas	Affiliated ARC Future Fellow
Tonti-Filippini	Julian	Affiliated Research Associate
Troesch	Josua	Technical Officer
Vacher	Michael	Research Associate - ECR
Van Aken	Olivier	Affiliated Research Fellow
Van der Merwe	Margaretha (Marna)	Affiliated Researcher - DECRA
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
Ward	Katherine	Accounts and Purchasing Officer
Waters	Mark	Future Fellow
Wijerathna Yapa	Akila	PhD Student
Yeoman	Deborah	Accounts and Purchasing Officer
Zhong	Xiao	PhD Student

AUSTRALIAN NATIONAL UNIVERSITY

Abdul Bahar	Nur	PhD Student
Ahmad Rashid	Fatimah Azzahra	PhD Student
Almonte	Andrew	Technical Officer
Alves Negrini	Ana Clarissa	Postdoctoral Researcher - ECR
Asao	Shinichi	Research Fellow
Atkin	Owen	Chief Investigator
Borevitz	Justin	Chief Investigator
Bowerman	Andrew	Affiliated Research Associate - ECR
Brown	Tim	Affiliated Research Fellow
Chan	Kai Xun	Postdoctoral Researcher - ECR
Coast	Onoriode	Research Associate
Collinge	Derek	Lab Manager
Crisp	Peter	Postdoctoral Researcher - ECR
Cullerne	Darren	Affiliated Research Associate - ECR
Eichten	Steven	Affiliated Researcher - DECRA
Fan	Yuzhen	Honours Student
Gaju	Reshmi	Affiliated Research Associate
Ganguly	Diep	PhD Student
Hawley	Naomi	Operations and Program Officer
Hayes	Lucy	Technical Assistant
Heussler	Alison	Technical Officer
Hou	Xin	PhD Student
Jones	Ashley	Technical Officer
Kariyawasam	Buddhima	PhD Student
McQuinn	Ryan	Postdoctoral Researcher - ECR
Moore	Marten	Technical Officer
Murray	Kevin	PhD Student
Phua	Su Yin	Senior Technical Officer
Pogson	Barry	Deputy Director and Chief Investigator
Posch	Brad	PhD Student
Rivers	John	PhD Student
Scafaro	Andrew	Visiting Fellow

AUSTRALIAN NATIONAL UNIVERSITY (CON'T)

Smith	Aaron	PhD Student
Spence	Matthew	Technical Officer
Stone	Beth	Honours Student
Supple	Megan	Postdoctoral Researcher - ECR
Taghavi-Namin	Sarah	Research Associate - ECR
Tee	Estee	PhD Student
Tucker	Josephine	Technical Officer
Warthmann	Norman	Postdoctoral Researcher
Watkins	Jacinta	PhD Student
Wilson	Phillipa	Affiliated Postdoctoral Fellow
Worcester	Corey	Operations Manager
Xiang	Jen	Course Coordinator
Xiong	Xiaofeng	PhD Student
Yadav	Arun	Affiliated Postdoctoral Researcher- ECR
Zhang	You	PhD Student
Zhu	Linglin	PhD Student

UNIVERSITY OF ADELAIDE

Ahmad Sohaimi	Muhammad Khairul Hisyam	PhD Student
Bose	Jayakumar	Affiliated Researcher - DECRA
Byrt	Caitlin	Affiliated Researcher - DECRA
Chen	Zhongyu	Honours Student
David	Rakesh	Affiliate Researcher - ANDS
Feng	Xueying	PhD student
Gilliham	Matthew	Chief Investigator
Henderson	Sam	Postdoctoral Researcher - ECR
Kamran	Muhammad	PhD Student
Long	Yu	Research Fellow - ECR
Mafakheri	Ali	Research Assistant
McGaughey	Samantha	PhD Student
McKay	Daniel	Honours Student
Pearson	Allison	Research Fellow
Phan	Hoai Thi Thanh	PhD Student
Qiu	Jiaen	Postdoctoral Researcher ECR
Qu	Yue	PhD Student
Ramesh	Sunita	Postdoctoral Research Associate
Sai	Na	PhD Student
Scharwies	Johannes	PhD Student
Shelden	Megan	Affiliated Researcher - DECRA
Sohaimi	Muhammad	PhD Student
Sullivan	Wendy	Lab Manager
Tyerman	Stephen	Chief Investigator
Vandeleur	Rebecca	Operations and Research Manager
Watts-Williams	Stephanie	Affiliated Research Fellow -ECR
Wege	Stefanie	Affiliated Researcher DECRA
Wignes	Jonathan	PhD Student
Wu	Yue	PhD Student
Xu	Bo	Affiliated Postdoctoral Researcher- ECR
Yan	Yunqi	Honours Student

LA TROBE UNIVERSITY

Abeynayake	Shamila	Research Officer
Berkowitz	Oliver	Research Fellow
Hartmann	Andreas	PhD Student
Jost	Ricarda	Research Fellow
Kushner	Yafit	PhD Student
Liew	Lim	Postdoctoral Research Officer
Linn	Joshua	PhD Student
Lozano	Diego	PhD Student
Lu	Li	PhD Student
Lyu	Wenhui	PhD Student
Meng	Xiangxiang	PhD Student
Narsai	Reena	Research Fellow
Osorio	Marina Borges	PhD Student
Ren	Meiyan	PhD Student
Selinski	Jennifer	Postdoctoral Fellow - Humboldt Fellow
Wang	Yan	Research Fellow
Wang	Yinan	Bioinformatician
Whelan	Jim	Chief Investigator
Xu	Yue	Research Officer
Yi	Changyu	PhD Student
Zhou	Xishi	Visitng PhD Student

2017 Publication Fast Facts

- Total number of publications by Centre staff: 89
- Average impact factor: 7.56
- Publications in top journals (impact factor 10 and above): 15
- Top journals include Nature Chemical Biology, Genome Research, Trends in Plant Science, PNAS and The Plant Cell.

Ahrens CW, Supple MA, Aitken NC, Cantrill DJ, Borevitz JO, James EA (2017) Genomic diversity guides conservation strategies among rare terrestrial orchid species when taxonomy remains uncertain. ANNALS OF BOTANY 119(8):1267-1277

Bahar NH, Ishida FY, Weerasinghe LK, Guerrieri R, O'Sullivan OS, Bloomfield KJ, Asner GP, Martin RE, Lloyd J, Malhi Y, Phillips OL, Meir P, Salinas N, Cosio EG, Domingues TF, Quesada CA, Sinca F, Escudero Vega A, Zuloaga Ccorimanya PP, Del Aguila-Pasquel J, Quispe Huaypar K, Cuba Torres I, Butrón Loayza R, Pelaez Tapia Y, Huaman Ovalle J, Long BM, Evans JR, Atkin OK (2016) Leaf-level photosynthetic capacity in lowland Amazonian and high-elevation Andean tropical moist forests of Peru. NEW PHYTOLOGIST (in press)

Belt K, Huang S, Thatcher LF, Casarotto H, Singh K, Van Aken O, Millar AH (2017) Salicylic acid-dependent plant stress signalling via mitochondrial succinate dehydrogenase. PLANT PHYSIOLOGY 173(4):2029-2040

Blomme J, Van Aken O, Van Leene J, Jégu T, De Rycke RM, De Bruyne M, Vercruysse J, Nolf J, Van Daele T, De Milde L, Vermeersch M, Colas des Francs-Small C, De Jaeger G, Benhamed M, Millar AH, Inzé D, Gonzalez N (2017) The Mitochondrial DNA (mtDNA)-Associated Protein SWIB5 Influences mtDNA Architecture and Homologous Recombination. THE PLANT CELL 29(5):1137-1156

Bogdanović O, Lister R (2017) DNA methylation and the preservation of cell identity. CURRENT OPINION IN GENETICS & DEVELOPMENT 46:9-14

Bose J, Munns R, Shabala S, Gilliham M, Pogson B, Tyerman SD (2017) Chloroplast function and ion regulation in plants growing on saline soils: lessons from halophytes. JOURNAL OF EXPERIMENTAL BOTANY 68, 3129-3143

Buckberry S, Bianco-Miotto T, Bent SJ, Clifton V, Shoubridge C, Shankar K, Roberts CT (2017) Placental transcriptome co-expression analysis reveals conserved regulatory programs across gestation. BMC GENOMICS 18(1):10

Butler EE, Datta A, Flores-Moreno H, Chen M, Wythers KR, Fazayeli F, Banerjee A, Atkin OK, Kattge J, Amiaud B, Blonder B, Boenisch G, Bond-Lamberty B, Brown KA, Byun C, Campetella G, Cerabolini BEL, Cornelissen JHC, Craine JM, Craven D, de Vries FT, Díaz S, Domingues TF, Forey E, González-Melo A, Gross N, Han W, Hattingh WN, Hickler T, Jansen S, Kramer K, Kraft NJB, Kurokawa H, Laughlin DC, Meir P, Minden V, Niinemets Ü, Onoda Y, Peñuelas J, Read Q, Sack L, Schamp B, Soudzilovskaia NA, Spasojevic MJ, Sosinski E, Thornton PE, Valladares F, van Bodegom PM, Williams M, Wirth C, Reich PB (2017) Mapping local and global variability in plant trait distributions. PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES USA 114(51):E10937-E10946

Cai S, Chen G, Wang Y, Huang Y, Marchant B, Wang Y, Yang Q, Dai F, Hills A, Franks PJ, Nevo E, Soltis D, Soltis P, Sessa E, Wolf PG, Xue D, Zhang G, Pogson BJ, Blatt MR, Chen ZH (2017) Evolutionary Conservation of ABA Signaling for Stomatal Closure in Ferns. PLANT PHYSIOLOGY 174(2):732-747

Cheng R, Doerge RW, Borevitz J (2017) Novel Resampling Improves Statistical Power for Multiple-Trait QTL Mapping. G3: GENES, GENOMES, GENETICS 7(3):813-822

Clavijo BJ, Venturini L, Schudoma C, Accinelli GG, Kaithakottil G, Wright J, Borrill P, Kettleborough G, Heavens D, Chapman H, Lipscombe J, Barker T, Lu FH, McKenzie N, Raats D, Ramirez-Gonzalez RH, Coince A, Peel N, Percival-Alwyn L, Duncan O, Trösch J, Yu G, Bolser DM, Namaati G, Kerhornou A, Spannagl M, Gundlach H, Haberer G, Davey RP, Fosker C, Palma FD, Phillips AL, Millar AH, Kersey PJ, Uauy C, Krasileva KV, Swarbreck D, Bevan MW, Clark MD (2017) An improved assembly and annotation of the allohexaploid wheat genome identifies complete families of agronomic genes and provides genomic evidence for chromosomal translocations. GENOME RESEARCH 27(5):885-896

Cognat V, Morelle G, Megel C, Lalande S, Molinier J, Vincent T, Small I, Duchêne AM, Maréchal-Drouard L (2016) The nuclear and organellar tRNA-derived RNA fragment population in *Arabidopsis thaliana* is highly dynamic. NUCLEIC ACIDS RESEARCH 45(6):3460-3472

Coupel-Ledru A, Tyerman SD, Masclef D, Lebon E, Christophe A, Edwards EJ, Simonneau T (2017) Abscisic Acid Down-Regulates Hydraulic Conductance of Grapevine Leaves in Isohydric Genotypes Only. PLANT PHYSIOLOGY 175(3):1121-1134

Crisp PA, Ganguly D, Smith AB, Murray KD, Estavillo GM, Searle IR, Ford E, Bogdanović O, Lister R, Borevitz JO, Eichten SR, Pogson BJ (2017) Rapid recovery gene downregulation during excess-light stress and recovery in Arabidopsis. THE PLANT CELL 29(8):1836-1863

Crous KY, O'Sullivan OS, Zaragoza-Castells J, Bloomfield KJ, Negrini ACA, Meir P, Turnbull MH, Griffin KL, Atkin OK (2017) Nitrogen and phosphorus availabilities interact to modulate leaf trait scaling relationships across six plant functional types in a controlled-environment study. NEW PHYTOLOGIST 215(3):992-1008

Crous KY, Wallin G, Atkin OK, Uddling J, Af Ekenstam A (2017) Acclimation of light and dark respiration to experimental and seasonal warming are mediated by changes in leaf nitrogen in *Eucalyptus globulus*. TREE PHYSIOLOGY 37(8):1069-1083

Cserne Szappanos H, Muralidharan P, Ingley E, Petereit J, Millar AH, Hool LC (2017) Identification of a novel cAMP dependent protein kinase A phosphorylation site on the human cardiac calcium channel. SCIENTIFIC REPORTS 7(1):15118

Dubreuil C, Jin X, Barajas-López JD, Hewitt TH, Tanz S, Dobrenel T, Schröder W, Hanson J, Pesquet E, Grönlund A, Small ID, Strand A (2017) Establishment of photosynthesis is controlled by two distinct regulatory phases. PLANT PHYSIOLOGY 176(2):1199-1214

Duncan O, Millar AH, Taylor NL (2017) Isolation of Mitochondria, Their Sub-Organellar Compartments, and Membranes. METHODS IN MOLECULAR BIOLOGY 1511:83-96

Elurbe DM, Paranjpe SS, Georgiou G, van Kruijsbergen I, Bogdanovic O, Gibeaux R, Heald R, Lister R, Huynen MA, van Heeringen SJ, Veenstra GJC (2017) Regulatory remodeling in the allo-tetraploid frog *Xenopus laevis.* GENOME BIOLOGY 18(1):198

Fyllas NM, Bentley LP, Shenkin A, Asner GP, Atkin OK, Díaz S, Enquist BJ, Farfan-Rios W, Gloor E, Guerrieri R, Huasco WH, Ishida Y, Martin RE, Meir P, Phillips O, Salinas N, Silman M, Weerasinghe LK, Zaragoza-Castells J, Malhi Y (2017) Solar radiation and functional traits explain the decline of forest primary productivity along a tropical elevation gradient. ECOLOGY LETTERS 20(6):730-740

Ganguly D, Crisp PA, Eichten SR, Pogson BJ (2017) The Arabidopsis DNA methylome is stable under transgenerational drought stress. PLANT PHYSIOLOGY 175(4):1893-1912

Gowik U, Schulze S, Saladié M, Rolland V, Tanz SK, Westhoff P, Ludwig M (2017) A MEM1-like motif directs mesophyll cell-specific expression of the gene encoding the C4 carbonic anhydrase in *Flaveria.* JOURNAL OF EXPERIMENTAL BOTANY 68(2):311-320

Hafiz Che-Othman M, Harvey Millar A, Taylor NL (2017) Connecting Salt Stress Signalling Pathways with Salinity Induced Changes in Mitochondrial Metabolic Processes in C3 Plants. PLANT, CELL AND ENVIRONMENT 40(12):2875-2905

Henderson SW, Dunlevy JD, Wu Y, Blackmore DH, Walker RR, Edwards EJ, Gilliham M, Walker AR (2017) Functional differences in transport properties of natural HKT1;1 variants influence shoot Na^+ exclusion in grapevine rootstocks. NEW PHYTOLOGIST 217(3):1113-1127

Hocking B, Conn SJ, Manohar M, Xu B, Athman A, Stancombe MA, Webb AR, Hirschi KD, Gilliham M (2017) Heterodimerization of Arabidopsis calcium/proton exchangers contributes to regulation of guard cell dynamics and plant defence responses. JOURNAL OF EXPERIMENTAL BOTANY 68(15):4171-4183

Hooper CM, Castleden IR, Tanz SK, Aryamanesh N, Millar AH (2017) SUBA4: the interactive data analysis centre for Arabidopsis subcellular protein locations. NUCLEIC ACIDS RESEARCH 45(D1):D1064-D1074

Hooper CM, Stevens TJ, Saukkonen A, Castleden IR, Singh P, Mann GW, Fabre B, Ito J, Deery M, Lilley KS, Petzold CJ, Millar AH, Heazlewood JL, Parsons HT (2017) Multiple Marker Abundance Profiling: combining selected reaction monitoring and data-dependent acquisition for rapid estimation of organelle abundance in subcellular samples. THE PLANT JOURNAL 92(6):1202-1217

Huntingford C, Atkin OK, Martinez-de la Torre A, Mercado LM, Heskel MA, Harper AB, Bloomfield KJ, O'Sullivan OS, Reich PB, Wythers KR, Butler EE, Chen M, Griffin KL, Meir P, Tjoelker MG, Turnbull MH, Sitch S, Wiltshire A, Malhi Y (2017) Implications of improved representations of plant respiration in a changing climate. NATURE COMMUNICATIONS 8(1):1602

James AM, Jayasena AS, Zhang J, Berkowitz O, Secco D, Knott GJ, Whelan J, Bond CS, Mylne JS (2017) Evidence for Ancient Origins of Bowman-Birk Inhibitors from *Selaginella moellendorffii*. THE PLANT CELL 29(3):461-473

Jayasena AS, Fisher MF, Panero JL, Secco D, Bernath-Levin K, Berkowitz O, Taylor NL, Schilling EE, Whelan J, Mylne JS (2017) Stepwise evolution of a buried inhibitor peptide over 45 million years. MOLECULAR BIOLOGY AND EVOLUTION 34(6):1505-1516

Knaupp AS, Buckberry S, Pflueger J, Lim SM, Ford E, Larcombe MR, Rossello FJ, de Mendoza A, Alaei S, Firas J, Holmes ML, Nair SS, Clark SJ, Nefzger CM, Lister R, Polo JM (2017) Transient and Permanent Reconfiguration of Chromatin and Transcription Factor Occupancy Drive Reprogramming. CELL STEM CELL 21(6):834-845.e6

Kourghi M, Nourmohammadi S, Pei JV, Qiu J, McGaughey S, Tyerman SD, Byrt CS, Yool AJ (2017) Divalent Cations Regulate the Ion Conductance Properties of Diverse Classes of Aquaporins. INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES 18(11). pii: E2323

Kretzmann JA, Ho D, Evans CW, Plani-Lam JHC, Garcia-Bloj B, Mohamed AE, O'Mara ML, Ford E, Tan DEK, Lister R, Blancafort P, Norret M, Iyer KS (2017) Synthetically controlling dendrimer flexibility improves delivery of large plasmid DNA. CHEMICAL SCIENCE 8(4):2923-2930

Lee K, Han JH, Park YI, Colas des Francs-Small C, Small I, Kang H (2017) The mitochondrial pentatricopeptide repeat protein PPR19 is involved in the stabilization of *NADH dehydrogenase 1* transcripts and is crucial for mitochondrial function and *Arabidopsis thaliana* development. NEW PHYTOLOGIST 215(1):202-216

Li B, Tester M, Gilliham M (2017) Chloride on the Move. TRENDS IN PLANT SCIENCE S1360-1385(16)30204-7

Li L, Millar AH, Huang S (2017) Mitochondrial Lon1 has a role in homeostasis of the mitochondrial ribosome and pentatricopeptide repeat proteins in plants. PLANT SIGNALING AND BEHAVIOR 12(2):e1276686

Li L, Nelson CJ, Trösch J, Castleden I, Huang S, Millar AH (2017) Protein Degradation Rate in *Arabidopsis thaliana* Leaf Growth and Development. THE PLANT CELL 29(2):207-228

Li S, Ying Y, Secco D, Wang C, Narsai R, Whelan J, Shou H (2017) Molecular interaction between PHO2 and GI in rice. PLANT, CELL AND ENVIRONMENT 40(8):1487-1499

Liang LL, Arcus VL, Heskel MA, O'Sullivan OS, Weerasinghe LK, Creek D, Egerton JJG, Tjoelker MG, Atkin OK, Schipper LA (2017) Macromolecular rate theory (MMRT) provides a thermodynamics rationale to underpin the convergent temperature response in plant leaf respiration. GLOBAL CHANGE BIOLOGY (in press)

Linn J, Ren M, Berkowitz O, Ding W, Van Der Merwe MJ, Whelan J, Jost R (2017) Root cell-specific regulators of phosphate-dependent growth. PLANT PHYSIOLOGY 174 (3)

Liu X, Nefzger CM, Rossello FJ, Chen J, Knaupp AS, Firas J, Ford E, Pflueger J, Paynter JM, Chy HS, O'Brien CM, Huang C, Mishra K, Hodgson-Garms M, Jansz N, Williams SM, Blewitt ME, Nilsson SK, Schittenhelm RB, Laslett AL, Lister R, Polo JM (2017) Comprehensive characterization of distinct states of human naive pluripotency generated by reprogramming. NATURE METHODS 14(11):1055-1062

Manani DM, Ateka EM, Nyanjom SR, Boykin LM (2017) Phylogenetic Relationships among Whiteflies in the *Bemisia tabaci* (Gennadius) Species Complex from Major Cassava Growing Areas in Kenya. INSECTS 8(1)

Martin A, Brown CW, Nguyen DQ, Palmer WM, Furbank RT, Byrt CS, Lambrides CJ, Grof CPL (2017) Cell wall development in an elongating internode of setaria. GENETICS AND GENOMICS OF SETARIA 19:211-238

Millar AH, Taylor NL (2017) The Isolation of Plant Organelles and Structures in the Post-genomic Era. METHODS IN MOLECULAR BIOLOGY 1511:1-11

Murray KD, Webers C, Ong CS, Borevitz J, Warthmann N (2017) kWIP: The k-mer weighted inner product, a de novo estimator of genetic similarity. PLOS COMPUTATIONAL BIOLOGY 13(9):e1005727

Narsai R, Gouil Q, Secco D, Srivastava A, Karpievitch YV, Liew LC, Lister R, Lewsey MG, Whelan J (2017) Extensive transcriptomic and epigenomic remodelling occurs during *Arabidopsis thaliana* germination. GENOME BIOLOGY 18(1):172

Nefzger CM, Rossello FJ, Chen J, Liu X, Knaupp AS, Firas J, Paynter JM, Pflueger J, Buckberry S, Lim SM, Williams B, Alaei S, Faye-Chauhan K, Petretto E, Nilsson SK, Lister R, Ramialison M, Powell DR, Rackham OJL, Polo JM (2017) Cell Type of Origin Dictates the Route to Pluripotency. CELL REPORTS 21(10):2649-2660

O'Leary BM, Lee CP, Atkin OK, Cheng R, Brown TB, Millar AH (2017) Variation in Leaf Respiration Rates at Night Correlates with Carbohydrate and Amino Acid Supply. PLANT PHYSIOLOGY 174(4):2261-2273

Opalińska M, Parys K, Murcha MW, Jańska H (2017) The plant i-AAA protease controls the turnover of an essential mitochondrial protein import component. JOURNAL OF CELL SCIENCE 131(2). pii: jcs200733

O'sullivan OS, Heskel MA, Reich PB, Tjoelker MG, Weerasinghe LK, Penillard A, Zhu L, Egerton JJ, Bloomfield KJ, Creek D, Bahar NH, Griffin KL, Hurry V, Meir P, Turnbull MH, Atkin OK (2016) Thermal limits of leaf metabolism across biomes. GLOBAL CHANGE BIOLOGY 23(1):209-223

Paynter E, Millar AH, Welch M, Baer-Imhoof B, Cao D, Baer B (2017) Insights into the molecular basis of long-term storage and survival of sperm in the honeybee (*Apis mellifera*). SCIENTIFIC REPORTS 7:40236

Pornsiriwong W, Estavillo GM, Chan KX, Tee EE, Ganguly D, Crisp PA, Phua SY, Zhao C, Qiu J, Park J, Yong MT, Nisar N, Yadav AK, Schwessinger B, Rathjen J, Cazzonelli CI, Wilson PB, Gilliham M, Chen ZH, Pogson BJ (2017) A chloroplast retrograde signal, 3'-phosphoadenosine 5'-phosphate, acts as a secondary messenger in abscisic acid signaling in stomatal closure and germination. ELIFE Mar 21;6. pii: e23361

Prunier R, Akman M, Kremer CT, Aitken N, Chuah A, Borevitz J, Holsinger KE (2017) Isolation by distance and isolation by environment contribute to population differentiation in *Protea repens* (Proteaceae L.), a widespread South African species. AMERICAN JOURNAL OF BOTANY 104(5):674-684

Pružinská A, Shindo T, Niessen S, Kaschani F, Tóth R, Millar AH, van der Hoorn RA (2017) Major Cys protease activities are not essential for senescence in individually darkened Arabidopsis leaves. BMC PLANT BIOLOGY 17(1):4

Rodríguez-Calcerrada J, Li M, López R, Cano FJ, Oleksyn J, Atkin OK, Pita P, Aranda I, Gil L (2016) Drought-induced shoot dieback starts with massive root xylem embolism and variable depletion of nonstructural carbohydrates in seedlings of two tree species. NEW PHYTOLOGIST 213(2):597-610

Rodríguez-Calcerrada J, Rodrigues AM, Perdiguero P, António C, Atkin OK, Li M, Collada C, Gil L (2017) A molecular approach to drought-induced reduction in leaf CO_2 exchange in drought-resistant *Quercus ilex*. PHYSIOLOGIA PLANTARUM (in press)

Rogiers SY, Coetzee ZA, Walker RR, Deloire A, Tyerman SD (2017) Potassium in the Grape (*Vitis vinifera* L.) Berry: Transport and Function. FRONTIERS IN PLANT SCIENCE (in press)

Rowland L, Zaragoza-Castells J, Bloomfield KJ, Turnbull MH, Bonal D, Burban B, Salinas N, Cosio E, Metcalfe DJ, Ford A, Phillips OL, Atkin OK, Meir P (2016) Scaling leaf respiration with nitrogen and phosphorus in tropical forests across two continents. NEW PHYTOLOGIST 214(3):1064-1077

Rumman R, Atkin OK, Bloomfield KJ, Eamus D (2017) Variation in bulk-leaf ^{13}C discrimination, leaf traits and water-use efficiency-trait relationships along a continental-scale climate gradient in Australia. GLOBAL CHANGE BIOLOGY 24(3):1186-1200

Sasidharan R, Bailey-Serres J, Ashikari M, Atwell BJ, Colmer TD, Fagerstedt K, Fukao T, Geigenberger P, Hebelstrup KH, Hill RD, Holdsworth MJ, Ismail AM, Licausi F, Mustroph A, Nakazono M, Pedersen O, Perata P, Sauter M, Shih MC, Sorrell BK, Striker GG, van Dongen JT, Whelan J, Xiao S, Visser EJ, Voesenek LA (2017) Community recommendations on terminology and procedures used in flooding and low oxygen stress research. NEW PHYTOLOGIST 214(4):1403-1407

Scafaro AP, Negrini ACA, O'Leary B, Rashid FAA, Hayes L, Fan Y, Zhang Y, Chochois V, Badger MR, Millar AH, Atkin OK (2017) The combination of gas-phase fluorophore technology and automation to enable high-throughput analysis of plant respiration. PLANT METHODS Mar 21;13:16

Scafaro AP, Xiang S, Long BM, Bahar NHA, Weerasinghe LK, Creek D, Evans JR, Reich PB, Atkin OK (2017) Strong thermal acclimation of photosynthesis in tropical and temperate wet-forest tree species: the importance of altered Rubisco content. GLOBAL CHANGE BIOLOGY 23(7):2783-2800

Secco D, Whelan J, Rouached H, Lister R (2017) Nutrient stress-induced chromatin changes in plants. CURRENT OPINION IN PLANT BIOLOGY 39:1-7

Selinski J, Hartmann A, Deckers-Hebestreit G, Day DA, Whelan J, Scheibe R (2017) Alternative oxidase isoforms are differentially activated by tricarboxylic acid cycle intermediates. PLANT PHYSIOLOGY 176(2):1423-1432

Selinski J, Hartmann A, Kordes A, Deckers-Hebestreit G, Whelan J, Scheibe R (2017) Analysis of Posttranslational Activation of Alternative Oxidase Isoforms. PLANT PHYSIOLOGY 174(4):2113-2127

Shabala S, Munns R (2017) Salinity Stress: Physiological Constraints and Adaptive Mechanisms. PLANT STRESS PHYSIOLOGY Chapter 2, 2nd Edition (S. Shabala, Ed.) CAB International. pp 24-63.

Shelden MC, Vandeleur R, Kaiser BN, Tyerman SD (2017) A Comparison of Petiole Hydraulics and Aquaporin Expression in an Anisohydric and Isohydric Cultivar of Grapevine in Response to Water-Stress Induced Cavitation. FRONTIERS IN PLANT SCIENCE 8:1893

Stoll K, Jonietz C, Schleicher S, des Francs-Small CC, Small I, Binder S (2017) In *Arabidopsis thaliana* distinct alleles encoding mitochondrial RNA PROCESSING FACTOR 4 support the generation of additional 5' termini of *ccmB* transcripts. PLANT MOLECULAR BIOLOGY 93(6):659-668

Tan HS, Jacoby RP, Ong-Abdullah M, Taylor NL, Liddell S, Chee WW, Chin CF (2017) Proteomic profiling of mature leaves from oil palm (*Elaeis guineensis* Jacq.). ELECTROPHORESIS 38(8):1147-1153

Tcherkez G, Gauthier P, Buckley TN, Busch FA, Barbour MM, Bruhn D, Heskel MA, Gong XY, Crous KY, Griffin K, Way D, Turnbull M, Adams MA, Atkin OK, Farquhar GD, Cornic G (2017) Leaf day respiration: low CO_2 flux but high significance for metabolism and carbon balance. NEW PHYTOLOGIST 216(4):986-1001

Tcherkez G, Gauthier P, Buckley TN, Busch FA, Barbour MM, Bruhn D, Heskel MA, Gong XY, Crous K, Griffin KL, Way DA, Turnbull MH, Adams MA, Atkin OK, Bender M, Farquhar GD, Cornic G (2017) Tracking the origins of the Kok effect, 70 years after its discovery. NEW PHYTOLOGIST 214(2):506-510

Teixeira PF, Kmiec B, Branca RM, Murcha MW, Byzia A, Ivanova A, Whelan J, Drag M, Lehtiö J, Glaser E (2017) A multi-step peptidolytic cascade for amino acid recovery in chloroplasts. NATURE CHEMICAL BIOLOGY 13(1):15-17

Tonti-Filippini J, Nevill PG, Dixon K, Small I (2017) What can we do with 1000 plastid genomes? THE PLANT JOURNAL 90(4):808-818

Valensisi C, Andrus C, Buckberry S, Doni Jayavelu N, Lund RJ, Lister R, Hawkins RD (2017) Epigenomic Landscapes of hESC-Derived Neural Rosettes: Modelling Neural Tube Formation and Diseases. CELL REPORTS 20(6):1448-1462

Van Aken O, Pogson BJ (2017) Convergence of mitochondrial and chloroplastic ANAC017/PAP-dependent retrograde signalling pathways and suppression of programmed cell death. CELL DEATH & DIFFERENTIATION 24(6):955-960

Wainaina JM, De Barro P, Kubatko L, Kehoe MA, Harvey J, Karanja D, Boykin LM (2017) Global phylogenetic relationships, population structure and gene flow estimation of *Trialeurodes vaporariorum* (Greenhouse whitefly). BULLETIN OF ENTOMOLOGICAL RESEARCH 108(1):5-13

Waters MT, Flematti GR, Smith SM (2017) Assaying Germination and Seedling Responses of Arabidopsis to Karrikins. METHODS IN MOLECULAR BIOLOGY 1497:29-36

Waters MT, Gutjahr C, Bennett T, Nelson DC (2017) Strigolactone Signaling and Evolution. ANNUAL REVIEW OF PLANT BIOLOGY 68:291-322

Wege S, Gilliham M, Henderson SW (2017) Chloride: not simply a 'cheap osmoticum', but a beneficial plant macronutrient. JOURNAL OF EXPERIMENTAL BOTANY 68(12):3057-3069

Wen Z, Tyerman SD, Dechorgnat J, Ovchinnikova E, Dhugga KS, Kaiser BN (2017) Maize NPF6 Proteins Are Homologs of Arabidopsis CHL1 That Are Selective for Both Nitrate and Chloride. THE PLANT CELL 29(10):2581-2596

Xie H, Konate M, Sai N, Tesfamicael KG, Cavagnaro T, Gilliham M, Breen J, Metcalfe A, Stephen JR, De Bei R, Collins C, Lopez CMR (2017) Global DNA Methylation Patterns Can Play a Role in Defining Terroir in Grapevine (*Vitis vinifera* cv. Shiraz). FRONTIERS IN PLANT SCIENCE 8:1860

Xu B, Cheval C, Laohavisit A, Hocking B, Chiasson D, Olsson TSG, Shirasu K, Faulkner C, Gilliham M (2017) A calmodulin-like protein regulates plasmodesmal closure during bacterial immune responses. NEW PHYTOLOGIST 215(1):77-84

Xu B, Waters S, Byrt CS, Plett D, Tyerman SD, Tester M, Munns R, Hrmova M, Gilliham M (2017) Structural variations in wheat HKT1;5 underpin differences in Na^+ transport capacity. CELLULAR AND MOLECULAR LIFE SCIENCES 75(6):1133-1144

Yin G, Xin X, Fu S, An M, Wu S, Chen X, Zhang J, He J, Whelan J, Lu X (2017) Proteomic and Carbonylation Profile Analysis at the Critical Node of Seed Ageing in *Oryza sativa*. SCIENTIFIC REPORTS 7:40611

Ying Y, Yue W, Wang S, Li S, Wang M, Zhao Y, Wang C, Mao C, Whelan J, Shou H (2017) Two h-Type Thioredoxins Interact with the E2 Ubiquitin Conjugase PHO2 to Fine-Tune Phosphate Homeostasis in Rice. PLANT PHYSIOLOGY 173(1):812-824

Yue W, Ying Y, Wang C, Zhao Y, Dong C, Whelan J, Shou H (2017) OsNLA1, a RING-type ubiquitin ligase, maintains phosphate homeostasis in *Oryza sativa* via degradation of phosphate transporters. THE PLANT JOURNAL 90(6):1040-1051

Zhang X, Ivanova A, Vandepoele K, Radomiljac JD, Van de Velde J, Berkowitz O, Willems P, Xu Y, Ng S, Van Aken O, Duncan O, Zhang B, Storme V, Chan KX, Vaneechoutte D, Pogson BJ, Van Breusegem F, Whelan J, De Clercq I (2017) The transcription factor MYB29 is a regulator of *ALTERNATIVE OXIDASE 1*. PLANT PHYSIOLOGY 173(3):1824-1843

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