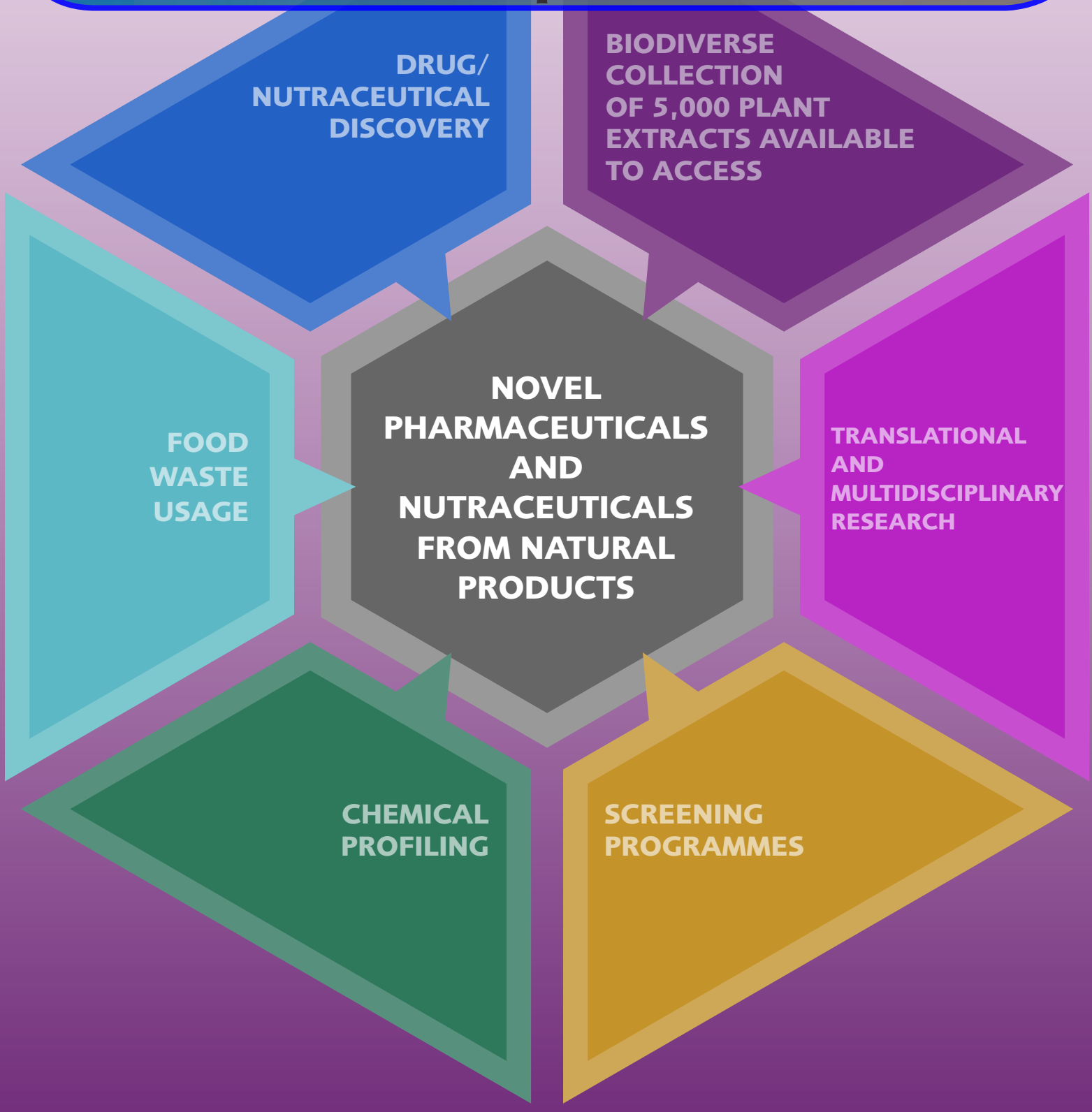
GARNish
December 2017: Edition 28

Harnessing the potential of natural products



Welcome to the December 2017 Issue of GARNish

Steven Spoel

GARNet Chairman

Once again welcome to this new issue of GARNish packed with news, views and reports from the UK plant science community. Although it has been another busy 6 months since our last issue I am often asked about what exactly the GARNet Advisory Board's activities are?

To illustrate this here I will highlight in a nutshell some of our key activities over the past 6 months. You will most likely be familiar with some of these but there are also others that you may not be aware of. First of all GARNet strives to make sure the UK Plant Sciences community remains as visible and productive as possible. Therefore we organise symposia and workshops that provide exposure to and training in new technological developments. Training the next generation of UK plant scientists in these rapidly emerging areas is of vital importance to the future and therefore we continuously offer early career researchers travel funds to attend our events.

We also support and co-fund activities from partner organisations to ensure linkage between fundamental, translational and applied research within the UK plant science community. If you have not already attended one of our many organised events, make sure to read through these pages or visit our website (www.garnetcommunity.org.uk) for announcements, meeting reports and other great resources for your research.

A lesser known activity of the GARNet Advisory Board is to ensure the UK plant science community remains competitive in the national and international life sciences research landscape. Therefore we liaise directly with funders, including the community's main funder, the BBSRC, and government to safeguard well-balanced future investments into the UK plant sciences. To deliver this we do not only have a BBSRC representative on the GARNet Advisory Board, we also provide in-depth direct recommendations. For example, in October we submitted a detailed response to a consultation on the future strategic directions of the BBSRC. Moreover, in September we responded to a call for evidence on life sciences and industrial strategy from the House of Lords Select Committee on Science & Technology.

As a community elected Advisory Committee, we are well placed to highlight and demonstrate to such organisations and governmental bodies the strengths and successes of the UK plant science community, especially during current uncertainties surrounding Brexit.

In this edition of GARNish we highlight events and meetings that GARNet have had the pleasure of attending. Over the past six months we have interacted with Brassica, Synthetic Biology, Arabidopsis and High Value Chemicals communitites. These interactions highlight our breadth of our interests and clearly respond to a key GARNet remit of supporting many aspects of UK plant science.

Elsewhere we highlight the Natural Products Resource based at Robert Gordon University, introduce the Plantae community resource and explain how statistics enhance agricultural research.

A great way for you to stay up to date with the research advances of the community is by looking at our blog (http://blog.garnetcommunity.org.uk/), our GARNet YouTube channel, and of course this issue of GARNish, which is once again has plenty of exciting news and views from around the UK.

IViews expressed by authors in GARNish are their own opinions and do not necessarily represent the view of GARNet or the BBSRC.

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Thanks to Steven Spoel, Kirsty Hassall, Mary Williams, Jonathan Carruthers, Sarah Jose, Cherry Wainwright, Janina Tamborski, Judith Glasson and the BBSRC grant holders.

> Cover image: Robert Gordon University

The GARNet Committee

UK Plant Sciences Federation Update

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Ongoing work on development of our Roadmap for UK Plant Sciences has been a major focus of activity for the UKPSF in 2017. The project has now reached an important milestone: a period of extensive external review. The draft report has been circulated widely among members of the plant science community, including funders, Government staff, and researchers in academia and industry, among others. Views from across the breadth of the plant sciences will be incorporated into the report to create a strong set of recommendations for decision-makers. The UKPSF will mark the launch of the Roadmap with a one-day meeting in Westminster in June of 2018, to which plant scientists and policymakers will be invited to discuss its main findings and themes.

This summer, the UKPSF, with support from Defra, provided the opportunity for four undergraduate students to undertake paid research placements with plant health researchers at UK institutions. In its first year, the Plant Health Undergraduate Studentships (PHUGS) scheme attracted 145 student applications for the four available places. The students awarded placements conducted research aimed at addressing major plant health challenges identified by Defra, by investigating the transmission of plant viruses, for example. As a result of their experiences, the four students all said that they were considering studying topics relevant to plant health once back at university, and three of the four are now considering further research in the discipline, at Master's or PhD level. We hope to run the scheme again next year, in collaboration with other organisations offering similar opportunities.

Finally, 2017 has seen the initiation of our new monthly Plant Science Newsletter, providing a round up of plant science policy news stories. The newsletter has proved popular, and details to subscribe can be found here. https://www.rsb.org.uk/policy/groups-and-committees/ukpsf

Global Plant Council Update

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The GPC recently announced the launch of an exciting new initiative in the area of New Breeding Technologies. Together with our friends at GARNet, we co-organised the Society for Experimental Biology 'New Breeding Technologies in the Plant Sciences' workshop in July, bringing together experts and novices to discuss the latest advances in the use of the popular gene-editing technology, CRISPR-Cas9. Many attendees said they really enjoyed learning more about the regulatory issues surrounding gene editing around the world, as well as the amazing conference dinner featuring CRISPR-Cas9-edited cabbage grown by Professor Stefan Jansson (Umeå University, Sweden)!

At the time of writing this update, the European Commission and the governments of many other countries had not yet announced how CRISPR-Cas9-edited plants will be regulated. As an output of the New Breeding Technologies workshop, the GPC worked with a team of experts to produce a consensus statement on the role of genome editing in plant science and agriculture, which we hope will be used as a recommendation for future policy decisions surrounding these techniques.

If you'd like to learn more about New Breeding Technologies, we have lots of resources on our website (http://globalplantcouncil.org/initiatives/new-breeding-technologies), including the consensus statement and technical and regulatory advice from the workshop.

CRISPR-Cabbage served up at the SEB/GPC Plant Satellite meeting

We've also been speaking to researchers around the world, both online and at conferences. You may have spotted our Executive Director Ruth Bastow telling attendees of the 2017 International Conference on Arabidopsis Research in St. Louis (Missouri, USA) all about our work, and again at the American Society of Plant Biologists meeting in beautiful Honolulu, Hawaii! Closer to home, I updated plant scientists on the progress we've made at the Society for Experimental Biology's annual meeting in Gothenburg, Sweden, and learned all about the latest breakthroughs in return.

As part of our Knowledge Exchange initiative, the GPC's President Bill Davies has been developing a 'Global Agricultural Practices Exchange' platform (GAPx) to aid in the translation of knowledge and skills from the lab to the field. We hope to help smallholder farmers in the developing world produce higher yields of nutritious food despite restricted inputs. Bill and his collaborators are working hard to make cutting-edge agricultural best practices and market information accessible from anywhere using mobile phones, and are developing both online and in-person training resources.

Speaking of sharing information, you can keep yourself updated on the latest plant science news via our website (http://globalplantcouncil.org/news-and-events/latest-news), or join the thousands of people who follow us on Twitter (@GlobalPlantGPC) or Facebook (http://www.facebook.com/GlobalPlantGPC). Our monthly Twitter blasts of international job opportunities have been very popular, so be sure to follow us if you're looking for your next career move!

If you're heading to Plant Biology Europe in Copenhagen next June, please consider selecting the option during registration to donate €5 to support the GPC in our mission to enhance collaboration and innovation in plant science around the world.

And finally, congratulations to our Outreach and Communications Manager, Lisa Martin, who welcomed the first GPC baby into the world earlier this year!

GARNet Workshop on Plant Gene Editing

March 26th-27th 2017,
University of Bristol

Organised by Helen Harper, Jill Harrison and Geraint Parry

GARNet in collaboration with the Bristol Centre for Agricultural Innovation and New Phytologist are delighted to be hosting a Plant Gene Editing workshop at the University of Bristol. Global CRISPR celebrity Stefan Jansson is providing the opening keynote lecture that will be followed by four sessions that explore the use of CRISPR-based technologies across plant species.

> Session I: Gene Editing in Dicots

> Session II: Gene Editing in Monocots

> Session III: Gene Editing and the Global Regulatory Landscape

> Session IV: Novel uses of Gene Editing Technologies

Each session includes a scheduled extended discussion that will allow delegates longer to question the speakers (and each other) to understand the best methods and techniques for tackling the challenges of gene editing technology.

The program has been designed to maximum interactions for early career researcher by including space for 9 talks from submitted abstracts and a poster session.

Due to kind support from the workshop supporters this meeting only costs £65 for ECRs, which also includes a conference dinner. Places are limited to 100 attendees so please register early for this meeting.

All the workshop details can be found here: https://garnet-ge-workshop.weebly.com/

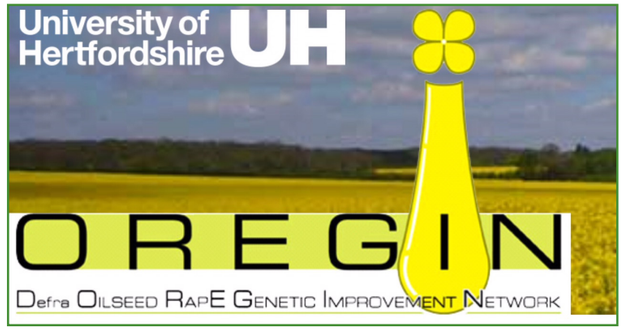
OREGIN Stakeholders Meeting

November 22nd 2017
University of York

The University of York hosted the OREGIN Stakeholders meeting that brought together academics, breeders and government officials to discuss the current status of *Brassica napus* (Oil Seed Rape, OSR) research and breeding.

OREGIN is one of the DEFRA funded 'Genetic Improvement Networks (GIN)' that support interactions between academic research and crop breeding in the UK. OREGIN is now hosted at the University of Hertfordshore where Professor Bruce Fitt leads a group of researchers who work on the pathology of a set of important OSR diseases; Phoma Stem Canker and Light leaf spot. The official OREGIN partners include the scientific lead Ian Bancroft at the University of York and a range of academic and industrial participants. The OREGIN grant also supports networking opportunities, which includes an annual meeting.

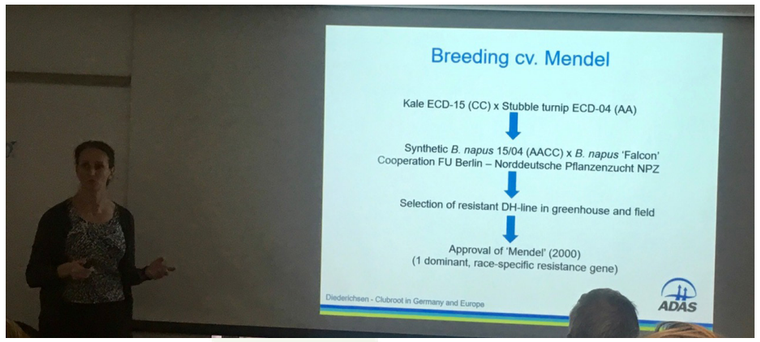
OREGIN Project partners



David Leaper kicked off the meeting by providing an interesting perspective from his work at the breeding company AGRII. This is an unusual view for academics to hear so it was gratifying to learn that farmers are often happy to integrate new technologies into their portfolio and are interested in interacting with researchers who have new ideas.

Leaper indicated that the UK market for OSR should remain healthy after Brexit as it is an important home rotation crop that farmers use between seasons growing more lucrative cereal crops. Leaper perfectly set the scene for the remainder of the talks by discussing some major challenges that OSR farmers can face. These include developing OSR traits to counter the effects of clubroot, Stem Canker, Turnip Yellow Virus and variable Pod shatter.

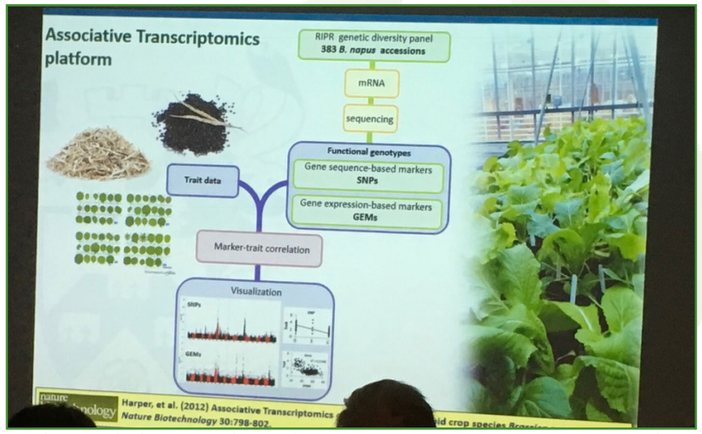
The talks were really well tailored for non-experts and included Julie Smith from ADAS who discussed AHDB-funded attempts to characterise UK-wide distribution of clubroot infection, which is more widespread that originally thought. Julie had a mixture of pessimism and optimisim about the present situation. Although the current OSR resistance is being eroded there still remains resistant germplasm in other Brassicas species so it is now critically important to exploit this variation.



Julie Smith outlines attempts to breed resistance to clubroot

John Walsh (University of Warwick) provided an overview of his groups work to develop resistance to Turnip Yellow Virus (TuYV). This has included attempts to resynthesize novel dual-resistant OSR (AACC genome) by crossing new resistant varieties of *B.rapa* (AA) and *B.oleracea* (CC). Following challenging embryo rescue and colchicine treatments they have successful generated OSR plants that are resistant to TuYV and are now attempting to introduce these traits into elite OSR varieties.

The meeting was characterised by talks with some really interesting unpublished data. Firstly Lars Ostergaard described his groups work on the factors that control pod shatter in both Arabidopsis and OSR. Lars discussed a new relationship that his group has discovered in Arabidopsis between the genes involved in pod shatter and the response to high temperature. They are now investigating this important agronomic trait in OSR.



Lenka Havlickova explains the Associative Transcriptomics pipeline

In the afternoon session Jose Gutierrez-Marcos introduced the work his group has done to evaluate the genetic elements that control the formation of double haploid populations in *Brassica oleracea*. In addition they are using CRISPR-Cas9 gene editing and have developed a methodology that reduces the current transformation-time bottleneck that can make this technique excessively time consuming. Although this new technology is currently being patanted, Jose revealed it utilises a tissue culture step and has broad applicability across plant species. Given the intransigent nature of transformation for most crop species this technology has the potential to revolutionise plant genetic engineering! *We shall see…*

Finally Lenka Havlickova from the Bancroft group at the University of York discussed the germplasm resources that their groups have developed. She described the many success stories using their Associative Transcriptomics technique to identify novel loci that response to different environmental stimuli. In addition Lenka described their resequenced gamma-irriadiated OSR panel that is also available for screening.

These remain exciting times for UK Brassica research that is outstandingly supported by the available germplasm and analysis tools at York, Nottingham and Norwich Research Park. The evolutionary similarity between Arabidopsis and Brassica crops makes this an obvious 'applied route' for researchers who work with model organisms. Recent developments in Brassica gene editing technology will reduce the activation barrier for others to work on these crops so watch this space for more exciting findings.

Connect with plant scientists at Plantae

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American Society of Plant Biologists

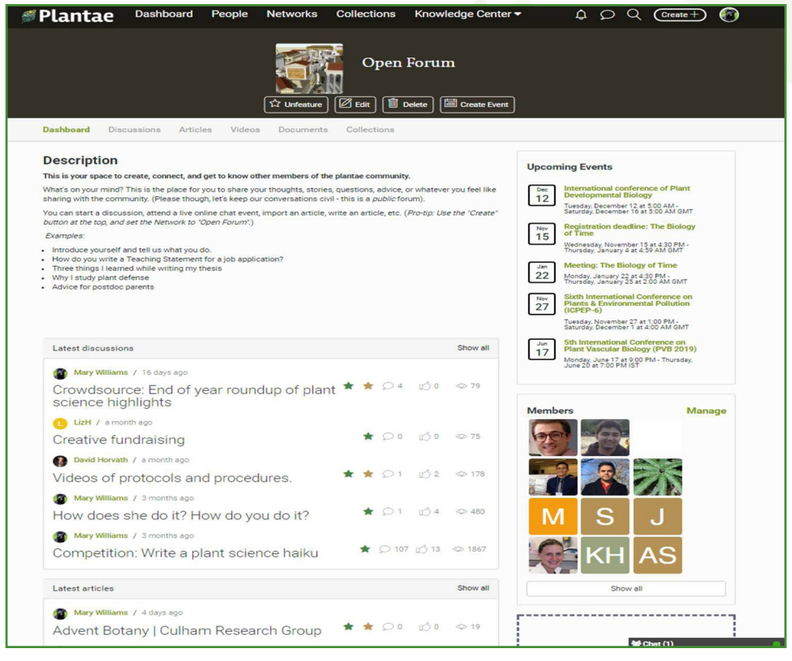
Recently at ASPB (American Society of Plant Biologists) we've been thinking a lot about how we can support early-career researchers no matter their career goals. This is one of the motivations of developing the Plantae platform: to provide an online home for plant scientists across the globe and career spectrum, to allow informal communities and learning groups to form, and to provide a supportive environment for scientists to engage in discussion groups and develop skills as science communicators. The Plantae initiative is powered by ASPB and was originally developed in partnership with the Global Plant Council.

Plantae is now a couple of years old, but the original technology was not supporting our goals so we relaunched an enhanced and updated version of Plantae on a new platform in June 2017. Plantae consists of three main hubs, the Plantae Blog (www.plantae.org) and the Plantae Community (www.community.plantae.org), and the Plantae job board (http://jobs.plantae.org/). The Plantae blog is where you'll find and the latest updates, highlighted resources, What We're Reading (a weekly series of short research summaries produced with contributions from members of the community and the Plantae Fellows), and much more. A short video demonstrating the features of this hub can be found on the blog. If you'd like add a resource to the Plantae blog, please contact Mary Williams (mwilliams@aspb.org).

The Plantae Community is where you're in charge. You can set up your profile (soon to include integration with ORCID), start a discussion, join a network, browse free webinars and online workshops, search for jobs, find a mentor, live-chat with peers, get feedback through inline comments and annotation, and more.

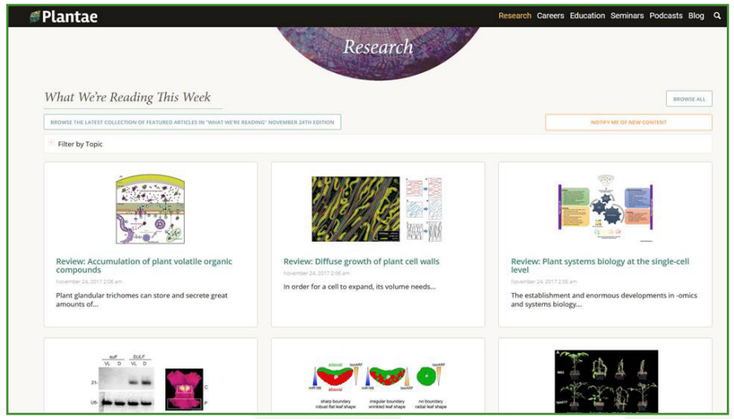
Here are a few ways to use the Plantae community site:

> Set up your profile with a photo, biography, publications list, and include your interests, affiliations and education and experience. Connect others with similar interests or affiliations (like LinkedIn).



> "Follow" people, or a resource or discussion, to see their activity in your timeline (like Twitter or Facebook).

> Join a network and receive notifications of new activity within the network. Activity can include discussions, new articles added, or event listings. For example, you can join the Plant Phenomics group to learn more about Phenomics, browse articles and participate in discussions. The WAVETT group (WordPress, Audacity and Video-Editing Tools and Tips) is a collaborative learning group focused on tools for science communication.



> Set up a private network for your class or working group. Work collaboratively on documents, share resources and participate in live chats. Right now there are numerous private networks that you can't see – if you'd like more information or a tour of how these are being used get in touch at community@plantae.org.

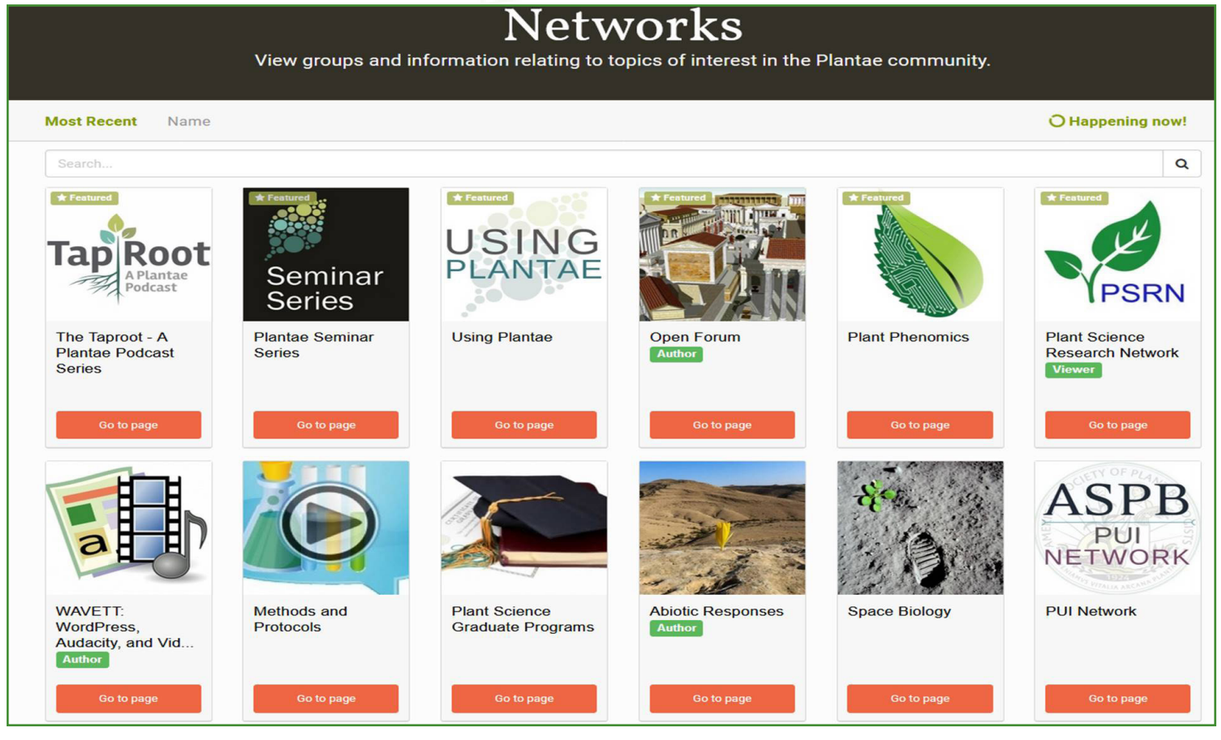
> Organize resources into a shared or private Collection. See for example the collection of 'On the Inside' articles from Plant Physiology.

> Enter our monthly competition for a chance to win a prize. Visit the Open Forum network for more information!

> Share videos. It's easy to upload videos from YouTube or Vimeo by simply dropping in a link. You can add videos you've made, videos you use for teaching, or curate a set of lectures. You can also browse the video collections from The Plantae Seminar Series, or the Between the Palms Interviews with Plant Scientists series.

> Want more help? Check out the Using Plantae network for videos and tutorials.

Some of the new projects we're working on now include a network for those attending (or interested in) the Phenomics 2018 meeting, Season 2 of the TapRoot podcast, and a writing club, so be sure to visit Plantae.org often for updates, and follow us @Plantae_org and on facebook!



Using Statistics in Plant Science

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Applied Statistics Group,

Rothamsted Research

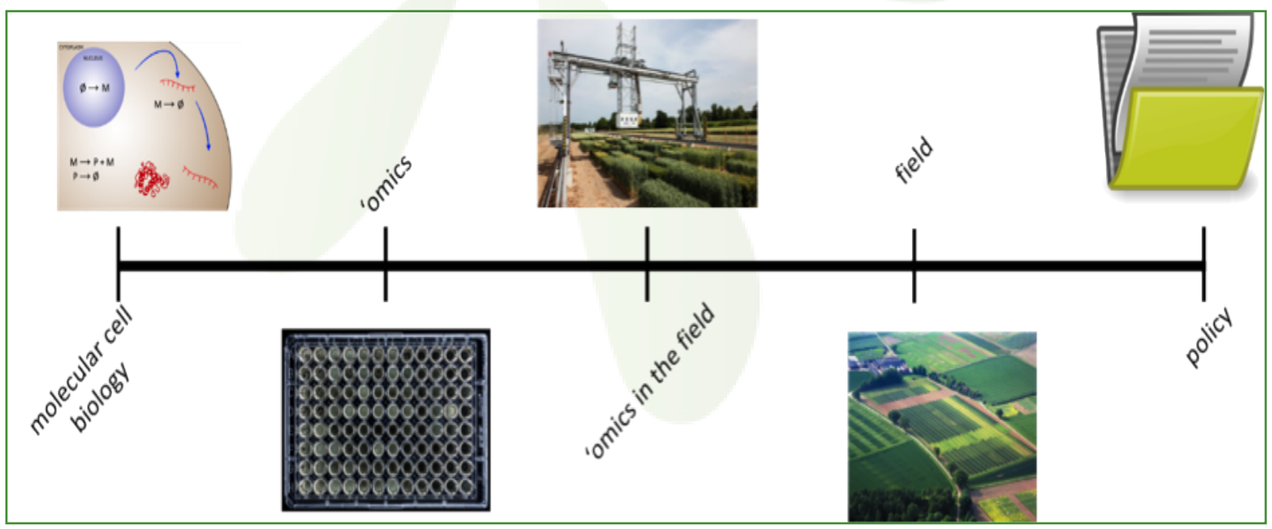
When asked what I do and my response is "*I'm a statistician*", I'm often faced with dismay and uncertainty "Oh…", later followed by "so what do you actually do?".

Well, what does an applied statistician working in an agricultural research institute actually do? At Rothamsted Research we are a team of five applied statisticians with varying areas of expertise and experience. The majority of our work is inward looking and broadly involves three different but interacting roles; providing consultancy for staff and students, delivering training and engaging in collaborative research to add value to agricultural and biological science.

Perhaps, some of the dismay attached to statisticians is the association with the need to "get more (or better) data". It is far too easy to be critical of data with the benefit of hindsight. Sometimes, issues are unforeseeable for example a piece of equipment failing midway through an experiment or a period of heavy rain preventing planned sampling in the field. *However, good statistical design can mitigate the impacts of such unplanned issues*. Perhaps it's no surprise that I mention statistical design. It was at Rothamsted almost 100 years ago that Fisher developed the foundations to statistical design, the ideas of replication and randomization with the result that it is now well-known that experiments with a good statistical design will be able to partition the biological variability from the background variability, i.e. to find the signal within the noise. Although, the ideas of design have been around for a long time, it is not always as simple as it sounds.

Statistical design principles are important for studies at all scales, from laboratory, through to CE and glasshouse, to field and landscape. Statisticians have a responsibility to deliver sound design principles to many different circumstances in order to ensure the scientific hypotheses can truly be answered and moreover, statistical design ensures the best use of resources (and yes, it has been known to have the discussion "with this design, you can get away with fewer replicates"). With this in mind, a particularly important part of our role is to encourage "full disclosure" through which the interplay between project aims, data collection, and analysis techniques can be assessed in order to get the most out of the available resources.

Training forms a key component of our role within the Institute. Modern biological research is increasingly quantitative, generating



New Phytologist — Research

N-terminomics reveals control of Arabidopsis seed storage proteins and proteases by the Arg/N-end rule pathway

Hongtao Zhang[1,2], Lucy Gannon[1], Kirsty L. Hassall[3], Michael J. Deery[2], Daniel J. Gibbs[4], Michael J. Holdsworth[5], Renier A. L. van der Hoorn[6], Kathryn S. Lilley[2] and Frederica L. Theodoulou[1]

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The Applied Statistics Group was involved in a recent Rothamsted-led publication

large and complex data sets. Consequently, scientists are expected to have a greater range of quantitative skills to deal with such data. In order to contribute to this, the Applied Statistics Group run a series of seven statistical training courses for staff and students covering topics such as design and analysis of experiments, regression and multivariate analysis and geostatistics.

The main aim of our training program is to give scientists a good grounding in a range of statistical concepts. We do not seek to make participants self-sufficient at all aspects of statistics, but rather to enable scientists to interact more effectively with statisticians on their specific data in the future through an awareness of both the key concepts and of the breadth of available statistical approaches. While the examples used in training courses can never consider all of the complexity associated with real-life problems, by using examples of data generated across the institute's research programme, we can demonstrate how statistical principles can be applied to cope with the range of challenges seen in agricultural and biological research.

Moreover, real-life examples often expose limitations in established methods of analysis. In particular, it is often the case that more information can be extracted from an experiment or dataset, but to do so requires more than the "standard" methods available. In this setting, it may be that analysis methods have to be developed or adapted in order to answer the specific questions of interest, thus highlighting the need to maintain good collaborative links with the wider statistical community.

The main reason why I like my job is the sheer variety in science, data and applications that I get to be involved with. Whether it's applications in molecular cell biology, analysis of data arising from new technologies, or projects aiming to inform policy, there's always something to learn.

Science is full of data of all shapes and sizes and the role statistics plays is always the same; to decouple various sources of variability and to try to find the signal within the noise. This principle is true whether it's trying to identify groups of similar transcripts through a cluster analysis, or curve fitting to model changes in biomass over time through linear and generalized linear models. Whether it's to identify peptides that show a significant change in relative abundance in a mutant plant line or identifying key lipids that are associated with differences in treatments through a principal components analysis.

Of course, the elephant in the room is the interpretation. This has to be a bilateral discussion between statistician and scientist to ensure both that the interpretation accurately reflects the data and that it is biologically relevant. An understanding of both the underlying science and the methods for analysis is essential to be able to draw meaningful conclusions.

If there's anything that I've learnt in my first few years working as an applied statistician in agricultural and biological research, it's that no two datasets or problems are the same, and that the methods needed to be able to extract the signal from the noise will always need to be specific to the problem at hand.

ROTHAMSTED
RESEARCH

Drugs and Nutraceuticals from Plants: a Birth or a Renaissance?

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Plants have been used in traditional medicine for centuries by many cultures, while more recently (over the last few centuries!) plant-derived chemicals, or structures based upon these chemicals, have made a significant contribution to modern western medicine. However, the natural product drug discovery process has traditionally been a rather cumbersome, and in some cases serendipitous, approach that depends upon systematic screening of extracts containing complex chemical mixtures, fractionation and ultimately chemical characterisation of the active ingredient.

Consequently, with the advent of combinatorial chemistry some 20-30 years ago, which aimed to produce vast numbers of small molecules that lend themselves to high throughput screening, natural product drug discovery fell out of favour. This was not only because of the protracted process of identifying biologically active compounds but also because of the difficulties faced when trying to synthesise the large and complex molecules that are the hallmark of plant-derived chemicals in the laboratory.

However, despite success in generating large libraries of small molecules, the combinatorial chemistry approach failed to generate any real significant drug leads. However, the development of new high throughput screening technologies and "omics" approaches (such as metabolomics) that facilitate the chemical characterisation and deconvolution steps in the natural product discovery pathway, has led to attention once again turning to natural sources to exploit the vast, and as yet undiscovered, biological and chemical diversity that exists in nature, not only in plants but other sources (including marine, algal and microbial biomasses) as leads for the next generation of drugs. Moreover, as health and wellbeing focuses increasingly on prevention rather than cure by using nutraceuticals and food supplements, there is a regulatory requirement to generate scientific evidence to support any health claims. Therefore, the underlying principles for natural product drug discovery are equally applicable to the discovery of these health products.

Leaves from Ginko Balboa – commonly used in Traditional Chinese Medicine and the source of some powerful anti-platelet agents

The Centre for Natural Products in Health, led by Professor Cherry Wainwright & Dr Giovanna Bermano at Robert Gordon University (RGU) in Aberdeen, is in the business of searching for new natural product-derived chemicals or extracts for both the prevention (nutraceuticals and food supplements) and treatment (new drugs) of cardiometabolic and obesity-related co-morbidities (e.g. certain forms of cancer, Type II diabetes and liver disease).

At the heart of these efforts is an extensive library of >5,000 plant extracts prepared from plant specimens collected from across the globe. The collection represents one of the most geographically, biologically and therefore most likely chemically diverse collections in existence, representing >90% of the world's plant families. The collection, which transferred to RGU from the University of Strathclyde in 2016, had already been screened for biological activity in ~30 screening assays, ranging from enzymatic screens through assessment of antioxidant activity, anti-microbial activity and anti-cancer potential, and several drug leads have been identified from the library over the 30 years of its existence. Today we are using a battery of screening methods, ranging from high-throughput cell-free and cell-based techniques to non-mammalian (C Elegans) and mammalian experimental models of disease, in our therapeutic areas of interest to exploit this collection of extracts in new directions. In addition to the plant extract collection, we have "diversified our interests to explore the potential biological activity contained in large biomasses, such as waste from the processing of agricultural crops for food or algae (seaweed) for production of industrial chemicals such as alginates.

While finding a "hit" may represent one small victory in the search for new natural product-derived biologically active chemicals, the steps from here to the production of a commercially viable product remains fraught with challenges:

Mixtures vs. Pure Compounds: Are the biological effects seen with an extract induced by a single chemical in the extract, or is it due to a combination of chemicals working together in a way that the result is greater than the sum of the parts? While modern drug discovery has traditionally focused on identification of a single molecule, traditional medicine (in particular Traditional Chinese Medicine) is largely based upon chemical mixtures and indeed there are at least two mixtures licensed for medicinal use by the FDA. Understanding the chemical profiles (e.g. through metabolomics) of our plant extracts would significantly help us answer some of these questions.

Extraction methods are typically chemical-based (usually organic solvents), which are expensive and difficult to undertake at scale. Also, chemical extraction may not work alongside the current "circular economy" trend to optimise the use of raw materials at every stage of the manufacturing life cycle. For example, if biomass that is currently used for animal feed (e.g. some food processing waste) could be exploited for high value chemicals prior to use as feed, then the extraction process needs to be compatible with this. Therefore "green chemistry" or non-chemical (e.g. microwave) extraction methods need to be developed.

Scale-up: In the event a single molecule is identified within plant material, scale-up production is also a challenge, not least because the complex chemical structures found in nature are difficult to synthesise in the laboratory.

Extraction from the original plant source is similarly challenging since the geographical, climatic and seasonal conditions under which the plant has grown will influence the chemical profile of the plant, and knowing what the "ideal" conditions are would prove a big task to establish. However, this is not unsurmountable, since the early attempt to produce the antimalarial drug artemisinin at scale from crop production was successful, if expensive. Moreover, mass crop production may not be suitable for rare plants found only in remote geographical locations. However, the use of cell factories and synthetic biology, using plant, bacterial, fungal and yeast cells, may offer a more cost-effective solution to this challenge, as has been demonstrated by the subsequent move of the production of artemisinin from a crop-based to a yeast-cell factory approach.

The natural product collection at RGU is accessible to researchers from academia, research institutions and industry on a pay to access basis, with materials provided under a material transfer agreement.

In addition to the 5,000 extracts, we also have a collection of dried plant material from a further 2,000 plants that have not yet gone through the extraction process.

If members of the GARNet community are interested in accessing the collection, or in collaborating with the Centre for Natural products in trying to address some of the challenges outlined in this article, then please make contact with either: Cherry Wainwright (c.wainwright@rgu.ac.uk) or Giovanna Bermano (g.bermano@rgu.ac.uk)

New BBSRC Grants featuring Arabidopsis Research

In the last edition of GARNish we noted that the amount of BBSRC responsive mode funding that supported fundamental plant science had declined in 2016 and wondered whether this was a blip or a more significant trend. To that end the GARNet Advisory committee will soon meet with a representative from the BBSRC to discuss this issue and to hopefully gain assurances that this type of plant science research remains an important component of the funding agenda.

Although GARNet does not wish to undermine the increased funding for more applied sectors of plant science it is clear that future innovation is underpinned by insights gained through work in model organisms. The GARNet committee will report back to the plant science community on any relevant findings.

Integration of UV-B and temperature signalling in plants

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Light and temperature are two of the most important signals regulating plant development. Plant thermomorphogenesis (developmental adaptation to non-stressful changes in ambient temperature) is a rapidly expanding field in plant biology with direct applications to crop productivity, ecology and biodiversity management in a changing climate. Although interactions between red/blue photoreceptors and high temperature signalling pathways have been identified, the integration of UV-B and high temperature signalling remains poorly characterised. UV-B, perceived by the photoreceptor UV RESISTANCE LOCUS 8, controls a wide variety of plant processes, including biosynthetic activity, several growth responses and protection against UV-stress.

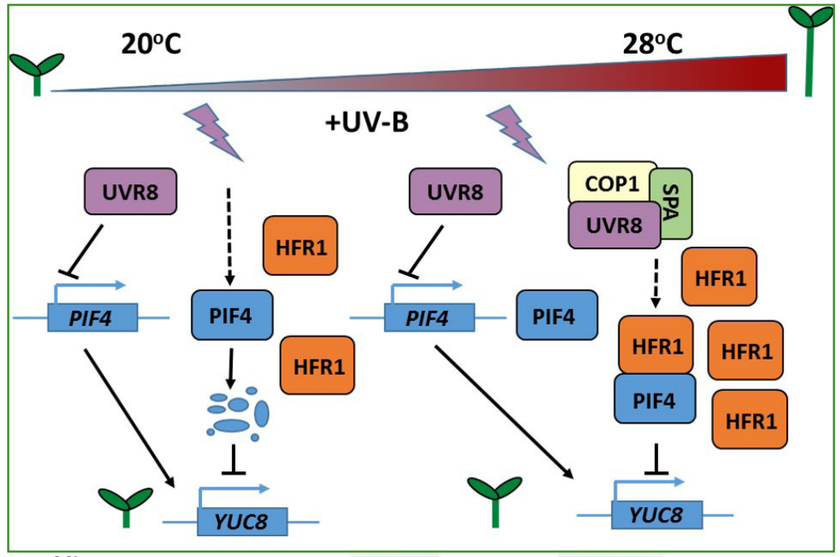
Leaf temperature increases concomitantly with UV-B absorption in sunlight-grown plants. In contrast to the situation in the field, the majority of plant science is carried out in glasshouses and growth cabinets, conditions in which plants are exposed to little or no UV-B. Understanding how UV-B and high temperature signals are integrated is therefore central to our understanding of plant development in natural environments.

Plants grown at warm ambient temperature display rapid stem elongation and elevate leaf angles from the soil surface. Modelling studies predict that these thermomorphogenic adaptations enhance transpiration and evaporative leaf cooling in well-watered environments. We and others identified a major molecular mechanism controlling Arabidopsis thermomorphogenesis.

High temperature enhances the abundance and activity of the bHLH transcription factor PHYTOCHROME INTERACTING FACTOR 4 (PIF4) which binds to genes involved in biosynthesis of the plant growth hormone, auxin. PIF4 increases auxin levels and promotes stem elongation. This process must, however, be tightly controlled as excessive stem elongation can lead to plant lodging and reduced survival. As such, plants have evolved multiple pathways to negatively regulate PIF4 abundance and activity.

We have shown that UV-B, perceived by UVR8, inhibits both PIF4 transcript accumulation and PIF4 function. The latter involves the transcriptional regulator HY5 HOMOLOG (HYH), but not its close relative LONG HYPOCOTYL 5 (HY5). In this new BBSRC grant, we will first explore the role of UV-B in suppressing PIF4 transcript abundance, through analyses of PIF4 promoter activity, transcript stability and chromatin remodelling at the PIF4 locus. The requirement for HYH (but not HY5) in UV-B-mediated thermomorphogenesis inhibition will be investigated via analyses of the abundance and post translational modification of both transcriptional regulators in a variety of light and temperature conditions. The possibility that HY5 and HYH compete for PIF4 target promoters in a manner conditional on the light and temperature environment will be explored.

This grant will deepen mechanistic insight in to the integration of light and temperature signalling pathways in controlling plant architecture. This information will help inform glasshouse lighting protocols in an ongoing collaboration with Vitacress Herbs (http://www.vitacress.com/herbs/).



Franklin: UV-B-mediated inhibition of thermomorphogenesis. UV-B perceived by UVR8 inhibits PIF4 transcript accumulation in a response requiring CONSTITUTIVELY PHOTOMORPHOGENIC 1 (COP1). This occurs independently of temperature and is accompanied by a decrease in endogenous PIF4 protein. At 20oC, UV-B simultaneously drives degradation of PIF4 protein and stabilises LONG HYPOCOTYL IN FAR RED 1 (HFR1). At 28°C, PIF4 is protected from UV-B-induced degradation but its transcriptional activity is inhibited by high HFR1 levels. HFR1 is stabilized at 28°C. In UV-B, UVR8 sequesters COP1, which may inhibit COP1-mediated HFR1 degradation. In high temperature and UV-B, high HFR1 levels inhibit PIF4 function. HYH performs a role in suppressing thermomorphogenesis and may function through competitive promoter binding of PIF4 targets such as YUCCA8 (YUC8). Taken from Hayes et al. (2017) Current Biology 27, 210-127.

Resolving the key photoprotective switch in photosynthetic electron transport

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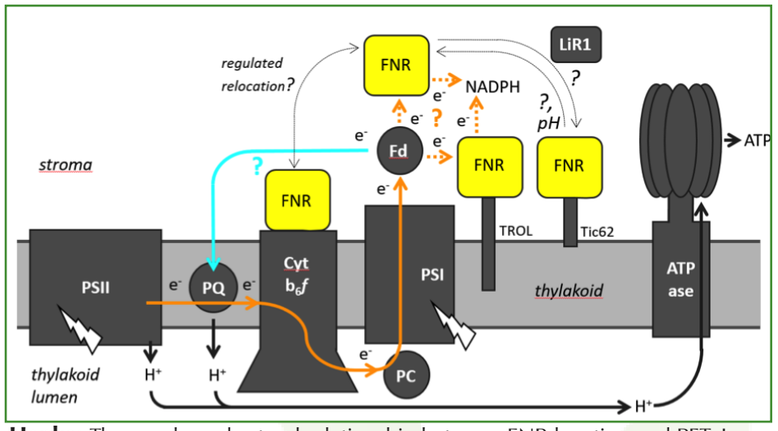
We aim to understand the way in which plants adapt to fluctuations in the environment, by studying a specific example that has the potential to improve crop plant tolerance to stress. In the final step of photosynthetic electron transfer (PET), the enzyme ferredoxin:NADP(H) oxidoreductase (FNR) uses photosynthetic electrons to reduce NADP+ to NADPH, which is then used in multiple reactions and is essential for C fixation. The amount of this enzyme has a strong effect (a high coefficient of control) on the entire pathway of photosynthesis (0.7 at low light and 0.94 at saturating light[1]). Interestingly, it has also been shown that the amount of FNR also strongly correlates with the ability of tobacco to tolerate multiple environmental stresses [2,3], although the reasons for this are not yet clear. We recently showed that variable FNR content and location results in disrupted free radical production from PET, and that this could be responsible for “priming” the plant, and inducing defence mechanisms [4].

FNR location within chloroplasts is highly dynamic, with many interaction partners (see Figure). The reason for these multiple interactions, the activity of the enzyme at variable locations and the relationship of different FNR-complexes with the rest of the PET apparatus is not understood. Important recent developments will enable us to finally understand these factors and how they relate to plant growth and stress tolerance.



Hanke: The poorly understood relationship between FNR location and PET. In linear electron flow (orange arrows) it has been variously suggested that FNR associated with PSI, or with TROL, or in a soluble state could catalyze NADP+ photoreduction. FNR has also been localised at the Cytb6f, leading to the proposal that it plays a direct, but as yet undefined, role in cyclic electron flow (blue arrows). Light treatment induces release of FNR from Tic62 and to a lesser extent from TROL, while re-recruitment is promoted in the dark by the LiR1 protein. Nothing is known about regulation of FNR recruitment during the light.

Firstly, we discovered that three FNR isoproteins from *Zea mays* specifically localise to different membrane complexes when transformed into *Arabidopsis thaliana* [5]. These have now been introduced to the *fnr1* mutant background, resulting in Arabidopsis lines with FNR localisation at specific chloroplast membrane complexes. This means we can now compare the activity of the enzyme, and its associated metabolic pathways, at different locations. Our novel plants will also allow us to pinpoint the interactions responsible for stress tolerance. Secondly, new equipment has been developed that will allow us to monitor the activity of the enzyme inside a living leaf [6].

Using these tools we aim to discover how dynamic redistribution of FNR is able to regulate PET and promote stress tolerance. Plants have limited resources available to them, and must allocate these to ensure the greatest chance of survival and reproduction. Improving the efficiency of switching between protective states and assimilatory states will therefore improve the chances of the plant not only surviving stressful conditions, but conducting rapid photosynthesis afterward and achieving a high harvest index. Better understanding of this regulation may help us to design or breed plants able to withstand specific stresses, or rapidly respond to the presence and absence of stresses in order to achieve survival but maintain high yields.

[1] Hajirezaei MR, *et al*. (2002) Plant J 29(3):281-93.
[2]: Palatnik JF, *et al*. (2003) Plant J 35(3):332-41.
[3]: Rodriguez RE, *et al*. (2007) Plant Physiol 143(2):639-49.
[4]: Kozuleva M, *et al*. (2016) Plant Physiol 172: 1480-1493.
[5]: Twachtmann M, *et al*. (2012) Plant Cell 24(7):2979-91.
[6]: Klughammer C, *et al*. (2016) Photosynth Res 128(2):195-214.

How do Phototropin Receptor Kinases Initiate Signalling from the Plasma Membrane?

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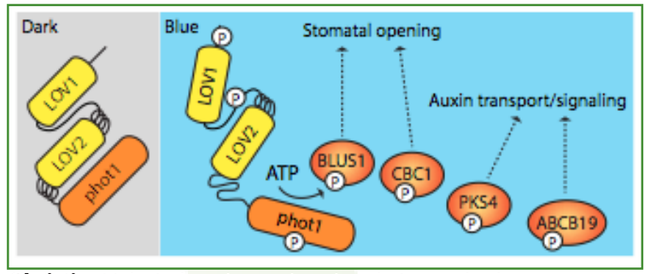
Improving crop yield has the potential to overcome the challenges facing global agriculture. Strategies to increase plant biomass have centred on enhancing photosynthetic productivity. Phototropins are plasma membrane-associated receptor kinases which are pivotal for plant growth and regulate a range of physiological processes that serve to optimise photosynthetic efficiency. Modulating phototropin function therefore offers considerable potential to manipulate plant growth through changes in photosynthetic performance. Indeed, genetic manipulation of phototropin-dependent stomatal opening has already proved successful in increasing yield. Extending this approach to coordinate further enhancements in photosynthetic efficiency will require a deeper understanding of how these light-activated kinases promote growth by maximising light capture, reducing photodamage and regulating gas exchange between leaves and the atmosphere.



Christie: Light-induced autophosphorylation and substrate phosphorylation by phototropin 1 (phot1). In the dark state, phot1 kinase activity is inhibited. Blue light drives a conformational change in the protein that results in autophosphorylation within the kinase domain, the linker region between the LOV domains and sequences upstream of LOV1. Concomitantly, phot1 can phosphorylate substrate targets including BLUS1, CBC1, PKS4 and ABCB19.

Phototropins are serine/threonine kinases that undergo autophosphorylation in response to blue light activation. The kinase domain of phototropin is located at the C-terminus of the protein, while light regulation of the kinase activity is mediated by the N-terminus of the protein, which contains two specialised domains designated LOV1 and LOV2. The primary photochemical events underlying phototropin activation by light are well understood. Yet, despite two decades of research, our understanding of how these autophosphorylating kinases are activated, how they are regulated and how they initiate signalling from the plasma membrane is far from complete. For instance, only four phototropin kinase substrates have been identified.

Phototropins are hydrophilic proteins, but are localised to the intracellular side of the plasma membrane. The mechanism underlying this attachment is still not known, but is thought to involve some form of lipid binding/modification. Light-dependent autophosphorylation rapidly promotes partial re-localisation of phototropin away from the plasma membrane, but the biological role of this translocation process has not been resolved. Dimerization is common among plant photoreceptors and phototropins are also reported to dimerize in a light-dependent manner *in vivo*. Yet, the impact of dimerization on phototropin autophosphorylation and signalling has not been investigated.

The objectives of our BBSRC-funded project (BB/R001499/1) are four-fold. We will: (1) Determine how phototropins associate with the plasma membrane and how light impacts the molecular conformation and localisation dynamics of early signalling events;

(2) Resolve the role of receptor dimerization in phototropin autophosphorylation and signalling;

(3) Characterise the contribution of autophosphorylation sites to phototropin function and determine the phosphatases required for reversible phosphorylation.

(4) Capitalise on recent progress in using a kinase engineering strategy, as well as genetic suppressor screening to identify new components of phototropin signalling. Together, these results will allow us to obtain a better grasp of the underlying mechanisms involved in phototropin signalling, which will be essential if we are to harness the full potential of altering phototropin function for agronomic gain.

Pathways to neo-functionalization: the past and future of strigolactone signalling

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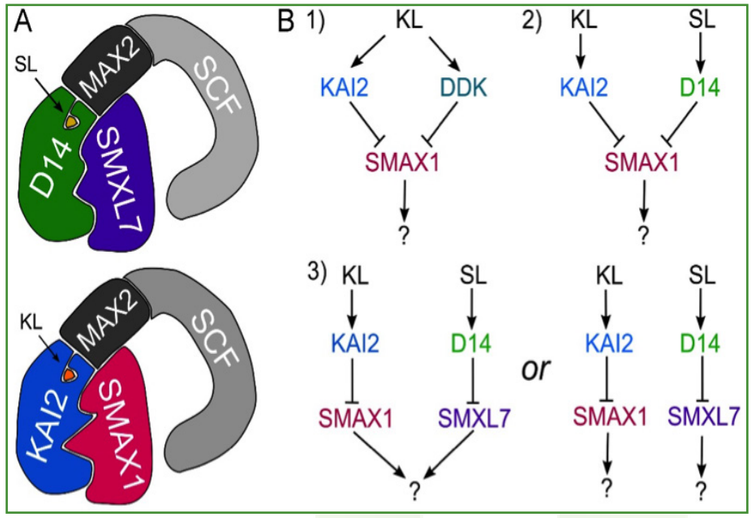
Hormonal signalling pathways are vitally important in the regulation of plant growth and development. Strigolactones (SLs) and 'KAI2-Ligand' (KL) are closely related hormonal signals that regulate specific aspects of development, including shoot branching, leaf morphology, root development, photomorphogenesis and seed germination.

In flowering plants, including most crop species, SL and KL act through very closely related signalling pathways to regulate development. SLs are perceived by D14, a hydrolase that acts as receptor; while KL is perceived by KAI2, a close homologue of D14. Both pathways signal



Bennett: A) Schematic representation of the SL and KL signalling complexes. B) Schematic representation of KL and SL signalling pathways in 1) liverworts, 2) gymnosperms and 3) flowering plants. In gymnosperms, both KL and SL seem to signal through the same downstream processes. In flowering plants, it is unclear whether the pathways are now completely separate, or still overlap downstream.

through the SCF^{MAX2} ubiquitin ligase complex to promote degradation of closely related members of the 'SMXL' family of chaperonin-like proteins (Soundappan *et al*, 2015; Plant Cell). Based on these data, it has been suggested that specific downstream responses to SL and KL are mediated by specific protein-protein interactions between D14-SMXL7 and KAI2-SMAX1, such that each signal only triggers degradation of the correct target (Waters *et al*, 2017; Ann Rev Plant Biol).

Our recent work has shown that in evolutionary terms, SL signalling appears to have arisen by duplication of the KL signalling pathway (Bythell-Douglas *et al*, 2017; BMC Biology). Indeed, D14-type receptors only arose in seed plants, and specific SL target proteins are only found in flowering plants. This suggests that outside flowering plants, these signalling pathways overlap either partially or wholly, and that both signals may trigger the same downstream responses. This raises very intriguing questions as to whether the signalling pathways in flowering plants are truly separate, or whether they may partially or even fully overlap.

Our BBSRC funded project (BB/R00398X/1) aims to investigate the specificity of SL and KL signalling using Arabidopsis to combine evolutionary-driven hypotheses with well-established molecular genetic and biochemical approaches. The overarching hypothesis that while SL and KL have highly specific upstream signalling pathways in flowering plants, they regulate development through the same downstream effectors. Firstly, we will create a receptor-target 'interactome' using proteins from across land plants, to test whether specific D14-SMXL7 and KAI2-SMAX1 interactions occur, and if so, when this may have evolved. We will use this information to map the receptor-target interface, and to understand how specificity arises at a structural level.

Secondly, we will assess whether SMXL family members are interchangeable in terms of downstream signalling, by using promoter swaps. We believe SMXL proteins perform have multiple downstream functions (Liang *et al*, 2016; Plant Cell), and will also use deletion mapping to ascertain whether certain domains of the proteins are associated with specific developmental outputs. Finally, we will attempt to identify the downstream targets of both KL and SL signalling in the context of lateral root development, and to generally characterise the role of both signals in root development with greater resolution.

Our ultimate goal is to assess the possibility of re-engineering SL/KL signalling pathways in crop plants to maximize yields through targeted alterations in shoot or root architecture.

BBSRC

GARNet Plant Gene Editing Workshop

University of Bristol

March 26th-27th 2018

www.garnet-ge.weebly.com

GARNet
University of BRISTOL
New Phytologist Trust

International Conference on Arabidopsis Research

St Louis Missouri, USA

Dr Janina Tamborski

The Sainsbury lab, Norwich, Norwich Researh park
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The most exciting (and to some the scariest) part of a large scientific conference such as the International Conference on Arabidopsis Research (ICAR) is finding the right opportunity to talk to leading scientists. Sometimes it is all about thinking on your feet, as was the case for me when my colleague knocked my drink out of my hand, resulting in a soda fountain that splashed all bystanders. Luckily one of them was Wolfgang Busch, who I had been meaning to talk to after his exciting seminar but previously lacked an opportunity to approach. After I apologised, we had a very productive discussion, proving that you can make lemonade when life gives you lemons (or a lemonade fountain).

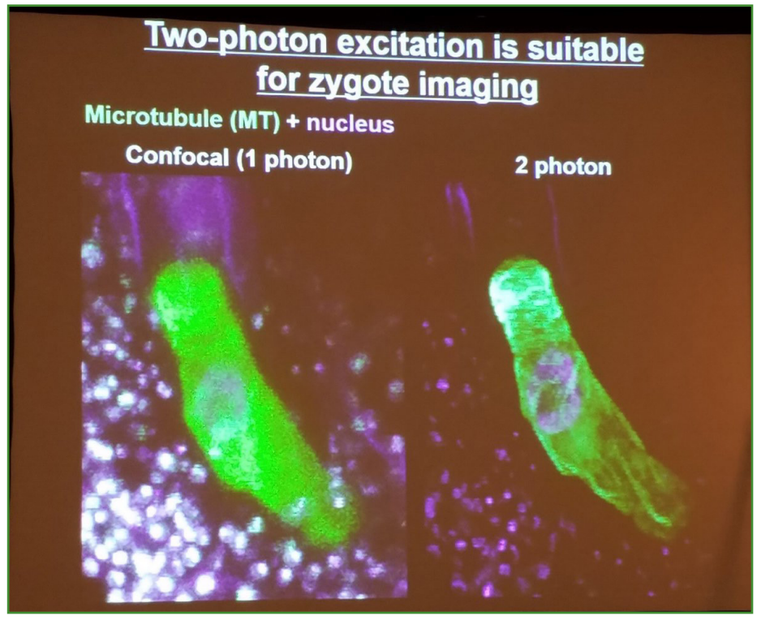
The 28th ICAR 2017 was held at the Hyatt and Donald Danforth Plant Science Center in St. Louis. With four keynote speakers, nine plenary, nine concurrent and two poster sessions, as well as six community organised workshops, it brought together many of the best scientists in Arabidopsis research. In addition to the five-day scientific program, there were also two career workshops for early career scientists that featured panellists from both academia and industry. The mixers afterwards offered career ideas and the opportunity to further expand ones' professional network.

The four keynote speakers represented the wide range of topics pursued in Arabidopsis research: Sabeeha Merchant talked about a day in the life of Chlamydomonas, Mary Lou Guerinot about ionomics and gene discovery, Keiko Torii shared her latest breakthroughs in synthetic biology and Sheng Yang He wanted to achieve understanding of the disease-climate-microbiome triangle.

Keiko Torii (Washington University) amazed the audience with her interdisciplinary approaches that arose from her close collaboration with researchers at the Institute of Transformative Bio-Molecules at Nagoya University. By engineering the auxin receptor TIR1 and creating a synthetic auxin ligand, she was able to show that the acid growth response is mediated by the TIR1 pathway. This is a prime example of how synthetic biology approaches can help us find answers to questions that have proven poorly tractable in genetics. Together with her screen of chemicals that influence stomatal patterning, her research promises to yield exciting results for us to watch out for in the future.

Of particular interest to me were the great talks on how Arabidopsis interacts with and manipulates its environment. Paul Schulze-Lefert's (MPI Cologne) work focussed on the microbiome of Arabidopsis and in particular on the endophyte C. tofildiae and its ability to promote growth and reproductive success of Arabidopsis under phosphate-limiting conditions. A successful interaction requires the host to have a functioning phosphate starvation response system and the ability to suppress its innate immunity. Cara Haney (The University of British Columbia) identified 93 genes and 63 operons in P. fluorescens that are required for survival on Col-0. She furthermore compared bacterial strains that trigger Induced Systemic Resistance (ISR) or Induced Systemic Susceptibility (ISS) that are 98% identical in their 16S RNA. Her lab identified a gene cluster that differs in ISS strains and she proposed that the production of spermidine through polyamine synthases is responsible for ISS.

Keiko Torii's intriguing title. Photo: Bethany Huot (@huotbethany)



Remarkable imaging of early embryogenesis by Minako Ueda
Photo: Bethany Huot (@huotbethany)

Niko Geldner (University of Lausanne) showed advances in understanding transport in the root and how the mutually exclusive localisation of lignin and suberin creates an active zone of uptake. Research from his group demonstrated that patchy transporter expression in roots correlates with the position of passage cells, forming a funnel-like pattern of cells to enable nutrient uptake in mature roots. Ute Kraemer (Ruhr University Bochum) unveiled how Arabidopsis thalianas' relative A. halleri, who can thrive on metalliferous soils, prevents cadmium accumulation and poisoning of the seeds. This cadmium tolerance is associated with a sequence polymorphism in HMA2 that leads to an early stop codon and renders the protein non-functional. Gregory Vert uncovered how the metal transporter IRT1 controls its own stability through recruitment of CIPK23 after excess metal conditions. CIPK23 consequently phosphorylates the E3 ligase IDF1 that mediates IRT1s K63 ubiquitination and leads to its endocytosis and degradation in the vacuole.

I particularly enjoyed the session "Novel Approaches", which showcased exciting tools from hormone biosensors (Alexander Jones, SLCU) to two-photon excitation microscopy (Minako Ueda, Nagoya University) and genome editing techniques (Dan Voytas, Minnesota Center of Genome Engineering). As a cell biologist, I could not help but be amazed by the images shown by Minako Ueda that showed cytoskeleton dynamics in the zygote in astonishing detail thanks to the high resolution achieved through two-photon excitation imaging. *[Minako will be travelling to the UK in September 2018 to participate in the GARNet2018 meeting- Ed]*

The meeting was rounded off by the last keynote speaker Sheng Yang He (Michigan State University) who managed to convey complex immune resistance and susceptibility concepts in an accessible manner. He discussed his recent publication that showed that bacterial effectors promote pathogenicity by transforming the air-filled apoplast into an aqueous environment for bacteria to flourish. His elegant approach to engineer the common host target COI1 to break the evolutionary dilemma of salicylic acid signalling was a case-study in the success of rational design in synthetic biology.

The 29th ICAR2018 will be held from the 25-29th June in Turku, Finland. I am excited to see how the Arabidopsis community continues to evolve. I hope to see the changes made at ICAR2017 continue, including the shift in hormone research from auxin-dominated to a focus on other hormones, in particular the brassinosteroids. Synthetic biology approaches were emerging in all disciplines and ranged from novel biosensors to receptor engineering. For the first time there was also an exciting session on translational biology that I would like to see again next year. I cannot wait to see what the conference next year in Turku has to offer.

http://icar2018.arabidopsisresearch.org/

UK Synthetic Biology at iGEM

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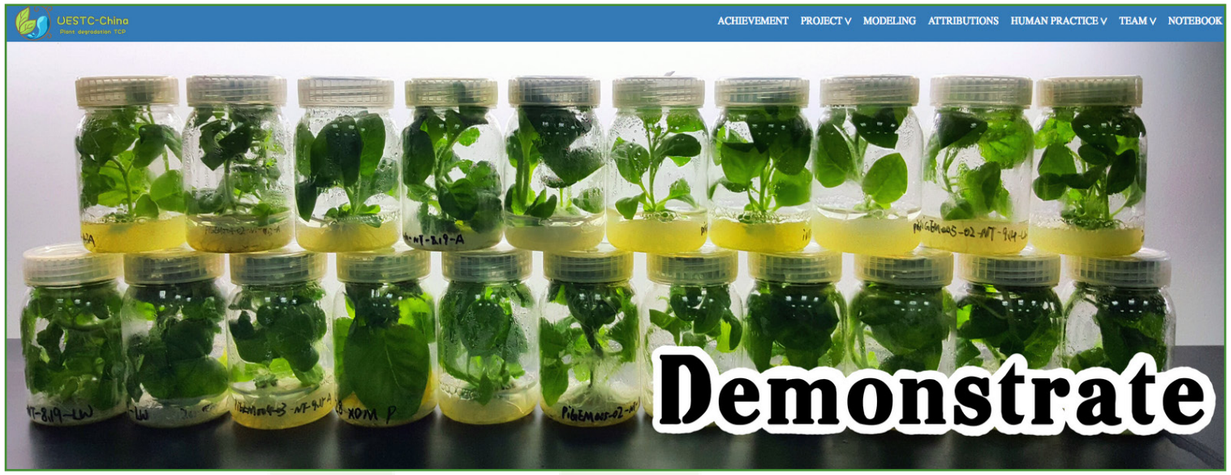
The giant jamboree that marks the end of the 2017 International Genetically Engineered Machine (iGEM) competition was again held in Boston, USA in mid November. This unique event brings together over 3000 students who present, demonstrate and discuss the novel research projects that they have worked on for the past year. These synthetic biology projects can be on any conceivable (safe) topic and are usually supported by academic institutions who, along with a range of sponsors, supply teams with up to £50K to fund the research, registration costs and transport.

The overall number of iGEM teams continues to rise with 295 having their entries finally accepted in 2017. Perhaps notably, 2017 is the first in which the number of Chinese teams was greater than those from the host nation. The number of UK teams has remained static over the past three years, with the identity of competing institutes often changing, no doubt caused by the high financial cost and time commitment needed to support projects and to send a group of students to Boston. Only Edinburgh, Exeter, Glasgow, Kent, Oxford, Sheffield, UCL and Warwick have supported teams in each of the past 4 years since the final jamboree moved to Boston.

The number of projects entered in the 'Environment Track' again increased this year and it was notable at this jamboree that there was an increased focus on ideas that involve plant science. Although this hasn't translated into a significant increase in the number of projects that are actually working WITH a plant synbio chassis, there is certainly an increased focus on finding solutions to global and local challenges that use plant-derived solutions. An example of this is from WashU St Louis whose project's ultimate goal was to improve plant resistance to damaging UV-B radiation. Although they discussed a possible collaboration with the Cardiff_Wales team who

iGEM from above showing all 3000 participants. http://2017.igem.org/Main_Page



UESTC-China: http://2017.igem.org/Team:UESTC-China

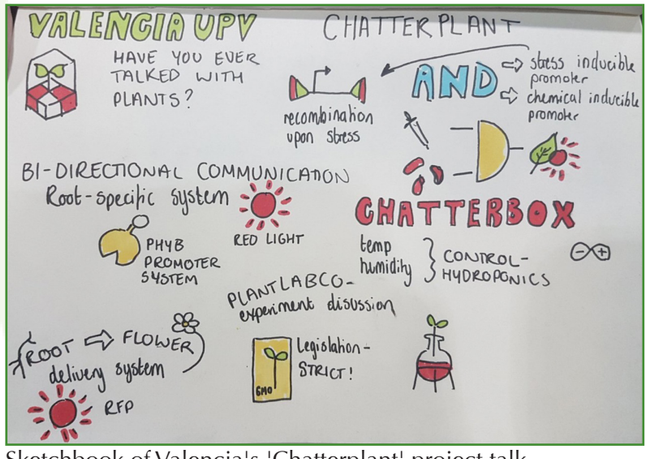
were using transient tobacco expression system as their experimental chassis, their work did not progress further than characterising their gene circuit in *E.coli*, which provided resistance to UV-B in that system. This type of project was more common than ever before, where bacterial synthetic biology was used as a starting point to tackle global problems that might ultimately involve plant science. http://2017.igem.org/Team:WashU_StLouis

However it was again pleasing to learn about some outstanding plant synbio projects. The plant synthetic biology lab in Valencia led by Diego Orzaez again excelled in this area, building hardware to monitor changes in plant growth in response to stress, a PlantLabCo software tool and also developing a root-expressed red-light sensor. Information about each of the Valencia projects from the past 4 years can be found here: http://igem.upv.es/

Arguably the most impressive plant project, and eventually winner of the Plant Synthetic Biology track, was from the UESTC-China team who had generated stably transformed tobacco plants expressing three biosynthetic enzymes. This Phytoremediation-based project was designed to remove the industrial atmospheric pollutant TCP. Lab experiments showed that transgenic leaf extracts were able to convert TCP to glycerol, demonstrating clear proof of concept. However during questioning, the challenge of this (and many other) iGEM projects was clear; the issue of scalability. How many tobacco plants would be needed to effectively reduce pollutants and where would these plants be grown? These questions were beyond the scope of this project and yet due to the required extra investment and future research time needed to provide satisfactory solutions, they might remain forever unanswered.

Elsewhere it was great to learn about the project from SECA-NZ who had managed to stably transform Arabidopsis plants with a frost-responsive gene from an Arctic plant; not an insubstantial task for a 6-month project!!

Judith Glasson from the team provides an account of the challenges of their project in an article on page 24.



Sketchbook of Valencia's 'Chatterplant' project talk
From Katy Baker: https://twitter.com/katherinevbaker

iGEM is a fantastic breeding group for innovative, with the competition allowing students to gain research and project management skills that set them on the path to careers in research and entrepreneurship. During his final address iGEM president Randy Rettberg encouraged iGEMers to go out and 'find the money'. iGEM also very strongly encourage responsible innovation so hopefully these messages can be successfully interwoven in future projects that current iGEM students will develop.

With UK synthetic biology heavyweights Imperial College (the 2016 overall winners) and the University of Cambridge absent from the 2017 competition, the UK community looked to others to pick up their slack....*and they did so with some significant success*! University teams from Exeter (overgrad Environment, Applied Design), Glasgow (undergrad, Food and Nutrition), Oxford (undergraduate Diagnostics), Edinburgh (overgrad Therapeutics) and Kent (undergrad Poster) all won 'Track awards' whilst Newcastle OG, Edinburgh UG, Manchester OG and Cardiff UG were also nominated for awards. This strong showing is only possible due to the matched funding that many teams receive from the BBSRC, SEB, Welcome Trust and Society of Microbiology.

iGEM is what it is, a tremendous international melting pot of ideas that is a fantastic experience to all those who participate. The competitive element can be challenging to assess with all teams judged equally with no consideration as to the level of institutional support, available financial resources, team size or length of project. Winning a medal or prize is ultimately a test of those parameters that might sit outside the actual research project so each team should take pride in what they have achieved within the limits of their ambition. The experiences gained by being involved in a nine-month (or more) multi-faceted research project that culminates in a global conference are not found easily elsewhere!

http://2017.igem.org/Main_Page

The Challenges of Plant SynBio at iGEM

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This year, I had the privilege of being one of the laboratory heads for SECA_NZ, the only iGEM team from New Zealand. The project we undertook for the competition was to investigate whether the ice recrystallization protein DaIRIP4, from *Deschampsia antarctica* (Antarctic hair grass), could be utilised to produce a commercial crop with intrinsic frost-resistance mechanisms. We knew the crops of interest to NZ growers (Kiwifruit, Grapevine, etc.) were too ambitious to tackle in the time available, so we began by characterizing the *in vivo* properties of DaIRIP4 in *Arabidopsis thaliana* to inform our future work.

It should be mentioned that I am not a plant biologist. I study biomedical science, as did my fellow lab head. There was, in fact, not a single plant biologist on the entire lab team. It was therefore quite an adjustment for us to leave behind the animal kingdom and commence our chosen project.

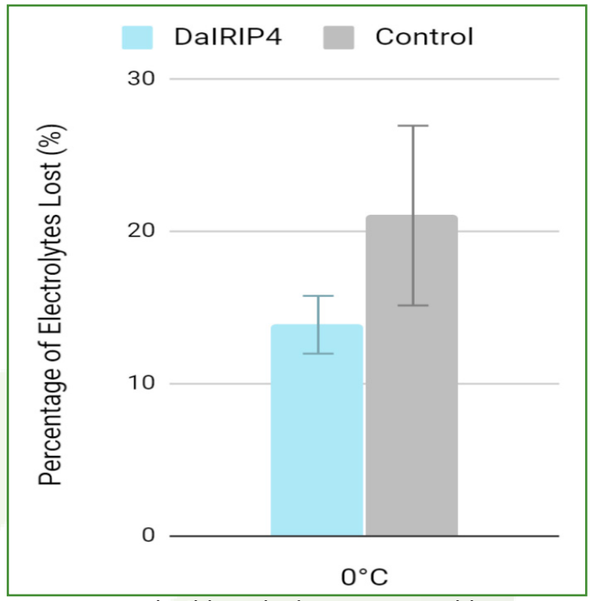
The first challenge we faced during this transition was containment. We had to undergo extensive training to be granted access to the PC2 plant facility, with operational independence in tasks such as planting and harvesting earned following repeated observations by fully trained personal. Even now, after almost 6 months of


Arctic Grass (*Deschampsia antarctica*)

continuous work, there are many boxes still to be signed off. Physical Containment 2 is a biosecurity containment above that needed for basic bacterial work (PC1), and includes precautions such as the passing of all liquids through filters sized at 100µm, and autoclaving of all waste materials on site.
http://www.mfe.govt.nz/publications/hazards/gm-nz-approach-jun04/genetic-modification-new-zealand

This reflects not only good scientific practice, but the GMO legislation in our country. "*In New Zealand you cannot import, develop, field test or release a genetically modified organism without approval from the Environmental Risk Management Authority*" (Ministry for the Environment, n.d.). Therefore, to operate under the existing approvals of our lab space, we could only produce plant to plant transgenic organisms. This lead to many promising proteins from fish and insect species being passed over. We settled on using DaIRIP4 due to its plant origin, ice binding properties, and previously demonstrated effectiveness at low concentrations. Furthermore, being a naturally cold-induced protein, it seemed like a good fit for our future work.

As with all good science, we required funds get our project off the ground. Through the amazing work of our finance team, over the course of the year we were able to raise $23000 NZD from local businesses willing to invest in our science and future business potential. This, combined with our twenty five page SWOT analysis and market strategy assessment lead to us being shortlisted for the Best Entrepreneurship award out of 300 teams at the iGEM competition.

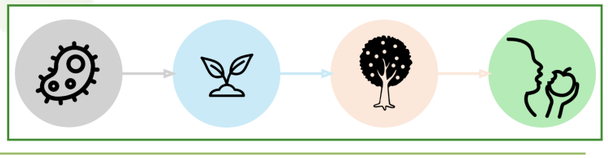


Transgenic and wildtype leaf response to cold stress

The initial part of the project, generating our construct for transformation, was familiar territory. Although some of the procedures were new, working with the bacteria and using the Gateway cloning system proved successful and time effective.

When it came to working with the Arabidopsis plants themselves, the process was blessedly uneventful. With the wonderful training from the students and postgraduate staff associated with the plant hall, we were able to not only transform our T0 population using the floral dip method, but also grow and test our T1 plants. Even more exciting was the acquisition of preliminary positive results.

With only 5 months of wet lab time and a team of 4 undergraduate students juggling their studies, I am incredibly proud of what we managed to achieve – including proving that working with a plant system was a lot less scary than it was made out to be.
http://2017.igem.org/Team:SECA_NZ



HVCfP Annual Meeting

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Hopefully most readers will be aware of the BBSRC funded Networks in Industrial Biotechnology and Bioenergy (NIBBs). These were established in 2014 with the overarching aim of establishing links between academics and industrial partners by providing a forum for interaction as well as funding of up to £50K for Proof of Concept grants or Business Interaction Vouchers. These grants are very much designed to overcome the threshold of interaction activity that often inhibits these type of activities. The ultimate aim is establish relationships that develop into longer term and potentially lucrative projects .

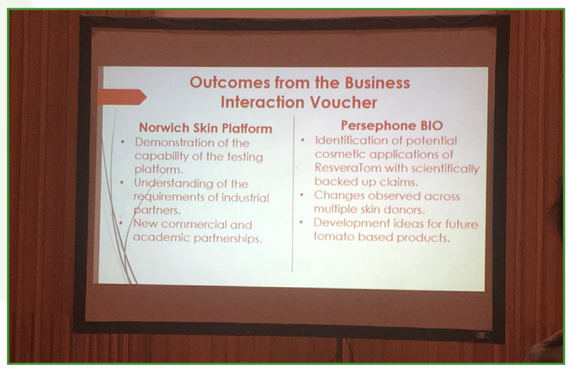
There were thirteen funded NIBBs with many of them involving some aspect of plant science. These include the Lignocellulosic Biorefinery Network (LBNet, https://lb-net.net/), the Plants2Product network (P2P, http://www.nibbp2p.org/), PhycoNet (http://www.phyconet.org.uk/) and the High Value Chemicals from Plants network (HVCfP, https://hvcfp.net/). There is clear overlap between NIBBs within common themes of bio-prospecting, bio-degradation and establishment of multi-product pipelines for efficient bio-extraction. Each of the NIBBs end in 2018 and the BBSRC has indicated that the funding will continue in some manner, although unlikely to remain in the same structure. The smart money predicts that in the next iteration there will be a reduced number of networks that bring together technologies that are used in several existing NIBBs.

It seems very important that the current modes of funding are maintained and even expanded as they have had the intended result of bringing together academics and industrial partners. The four-year time scale of the current NIBBs is unlikely to have been sufficient to establish full partnerships but might have been long enough to set relationships along the road to something more concrete. A full list of funded projects can be found in the NIBBs annual newsletter on the BBSRC website. http://www.bbsrc.ac.uk/research/programmes-networks/research-networks/nibb/

The HVCfP annual meeting was held in the acoustically excellent venue of Cheethams music school in Manchester and included three keynote speakers alongside shorter talks from other network members who described research that had been funded, at least in part, through the HVCfP NIBB. The opening keynote was provided by John Barratt (BASF) who gave a broad overview of the activities of a company that has an annual profit of £6billion and employ 3000 people just in R+D! On the plant side of R+D it was extremely interested to learn that current EU policy on the use of GMO was a significant factor in moving this department in China. I wonder whether this might be an opportunity for the UK post-Brexit with the chance to develop an evidence-based and product-focused regulatory environment that might attract overseas investment?

The global regulation of technology was also an issue for Marcelo Kern from Glaxo SmithKline who outlined one of their research projects that had to be eventually shelved because of the prohibitive cost of a licence for the commercial use of CRISPR-Cas9 technology. This is an issue that most academics do not consider yet is clearly significant to consider if basic research is able to successfully translate into the commercial arena.

The final keynote was a real success story provided by George Lomonossof from the John Innes Centre. He described the research journey that led from the basic research that enabled the characterisation of Virus-Like Particles (VLPs) and through the optimisation steps needed for high level production in the leaves of tobacco plants.



Damon Bevan on the BIV-interaction between UEA and PerspehoneBio

Richard Blackburn introduces his research that is looking at the use of British Liquorice in skincare products.

This finally led to the bricks and mortar of the Leaf Expression Systems building at Norwich Research Park and the altruistic and commercial potential of polio vaccine VLP production.

Throughout the day Proof of Concept grant award winners presented the outputs that had been made possible due to the funding provided through the network. Samuel Brockington (University of Cambridge) presented some recently published research that had characterised production of betalain pigments in beetroot (https://goo.gl/8PHSQ7). He demonstrated the successful heterologous expression of metabolic enzymes in the tobacco system and suggested that this might lead to future novel production strategies.

The cross-disciplinary nature of the HVCfP awardees was fantastically illustrated by a talk from Richard Blackburn who is a lecturer in Textiles at the University of Leeds and has been investigating the potential of using liquorice as a component of future skincare products. This work developed following a previous HVCfP event at which Dr Blackburn had learnt about this area of research from PhD student Keir Bailey who worked at the University of York.

Dr Damon Bevan works for the Norwich Skin Platform at UEA and they interact with PerspehoneBio (http://persephonebio.co.uk/), a company that has spun out of work on the production of novel compounds in tomato from Cathie Martin's lab at the John Innes Centre. This company is also based at Norwich Research Park and Dr Bevan received a Business Interaction Voucher (BIV) from HVCfP to test the anti-aging effects of novel plant products in a human skin bioassay.

The final BIV talk from Ray Marriott (Biocomposites Centre at Bangor University) highlighted a subtle yet significant change in emphasis of the talks at these HVCfP events. Professor Marriott's talk focused on the use of Vibratory Shear-Enhanced Process (VSEP) technology to better characterise botanical extracts. This demonstrated the shift in research techniques focused on molecular plant biology toward those that use more analytical chemistry-based strategies.

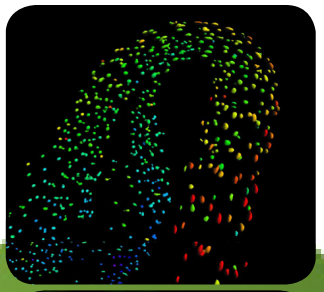
There remains a strong research base that manipulates biosynthetic pathways either *in planta* or using heterologous expression systems but there is clearly also growing interest in this area from chemists who are using a range of different technologies in order to identify, characterise and extract novel compounds from plants. These interactions highlight the multi-disciplinary nature of this research community and with follow-on funding it will be exciting to learn about the discoveries that will come out of the interactions that have been built up as part of the first round of NIBB funding.

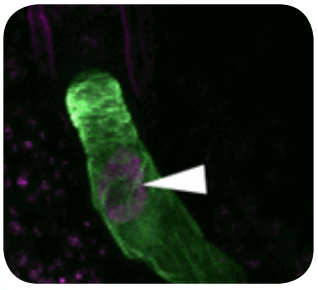
GARNet2018: a plant science showcase

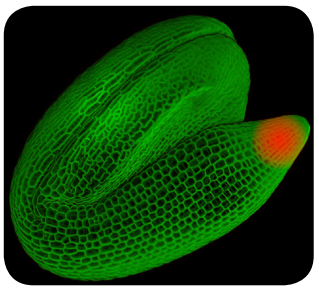
University of York
September 18-19th 2018

Five Plenary Sessions:
> *Large Scale Biology*
> *Innovations in Hormone Signaling*
> *Interacting with the environment*
> *Out of Arabidopsis*
> *Novel Cell Imaging*

> *Keynote: Prof Dame Ottoline Leyser*
> *10 talks from abstracts*
> *15 Flash presentations*







http://garnet2018.weebly.com/