GARNish
July 2020: Edition 33

Genomic Arabidopsis Research Network (GARNet): 2000-2020

The End of the Era of UKRI-BBSRC Funding

Welcome to the July 2020 Issue of GARNish

Geraint Parry, Cardiff University

GARNet Coordinator

Welcome to the July 2020 issue of GARNish, which will be the final edition as supported by UKRI-BBSRC responsive mode funding.

Over the past year the GARNet leadership team have been unsuccessful in attempts to continue the research network through UKRI funding.

We hope that success of GARNet will motivate UKRI to investigate possible mechanisms through which research networks might obtain longer term funding. UK plant science is world-leading yet there remains the need for research networks to add-value to funded activities through integration of infrastructures and training requirements.

In this issue of GARNish we provide a 'Potted History' of GARNet activities since 2000 and we are grateful to everyone who has contributed over the past twenty years. It is extremely exciting that the first GARNet PI, Ottoline Leyser, is now the CEO of UKRI, ensuring that plant science will have an equal place in strategy discussions at the highest level of scientific decision-making.

During GARNet's time a plant science success story has emerged at the University of Nottingham. Following the opening of the Plant Science Building at Sutton Bonington in 2001 they have expanded to be the largest academic plant science department in the UK. Therefore in this final edition of GARNish it seems fitting to turn the Spotlight on the research currently ongoing at Nottingham.

Contents

Special thanks to: Jonathan Carruthers, Isabel Mendoza, Darren Hassall, Malcolm Bennett, Jennifer Dewick, Marcel Bach-Pages, the BBSRC grant holders and the faculty members at Nottingham,

Elsewhere in this edition of GARNish we introduce the activities of the Crop Health and Protection (CHAP) Agritech Centre as well as the new UKRI-funded Bacterial Plant Diseases projects. We take a look at the papers that have been highlighted by the GARNet Research Roundup over the past five years as well as analysing recent global trends of Arabidopsis publications.

The primary goal of GARNet activities is to support new technologies and research excellence and we highlight a new technique for analysing the plant RNA-Interactome as well as introducing two newly BBSRC funded Responsive mode projects.

We aim for GARNet to remain a presence within the UK plant science community. We intend to continue multimedia outputs alongside investigating opportunities to provide training workshops based on new technologies.

The GARNet Advisory Committee

Arguably the most notable event for the future is the GARNet-organised International Conference on Arabidopsis Research (ICAR) that will take place in Belfast in June 2022. This global event will be at the very least a fitting tribute for the twenty years of GARNet activities in support of the UK plant science community.

We only hope that the new normal that emerges after the COVID crisis will allow us to enjoy each others company and develop collaborations away from a computer screen!

As always, stay up to date with @GARNetweets, our website (www.garnetcommunity.org.uk) and blog (http://blog.garnetcommunity.org.uk/).

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

UKRI Biotechnology and Biological Sciences Research Council

GARNish

Society Updates

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UK Plant Sciences Federation Update

Jonathan Carruthers

Royal Society of Biology

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The UK Plant Sciences Federation (UKPSF) is a special advisory committee of the Royal Society of Biology (RSB), made up of 21 organisational members from across plant science. 2020 is the International Year of Plant Health. While the COVID-19 pandemic has rightly foregrounded human health, it also serves to remind us of the importance of biosecurity, including threats to plant health. Plant Health and Biosecurity was a theme of Growing the future, the 2019 report from UKPSF, and we are developing activities that will play a part in raising public awareness and strengthening the plant health profession. UK biosecurity is also a strategic area of focus for RSB science policy activity across the biosciences. Moving forward UKPSF/RSB are playing a major role in the organisation of an innovative plant health conference which is scheduled for March 2021. Please keep an eye on our social media feed for more details on this exciting event, https://twitter.com/ukpsf.

In March, we awarded funding to 10 researchers to host Plant Health Undergraduate Studentships. The studentship projects have been deferred to run over the summer of 2021 (dependant on Government advice) to protect the health and welfare of students and supervisors. Support for this programme comes from Defra, BSPP, Crop Protection Association, SCI Horticulture Group, and the David Colegrave Foundation. Defra has kindly agreed to fund a further four studentships in 2021, so researchers will have another opportunity to apply to the programme early next year. This represents a substantial growth in the number of students we are able to support through this impactful programme.

GARNet was a founding member of UKPSF, and has played an important role throughout the Federation's existence, including the GARNet coordinator Geraint Parry being current chair of the UKPSF advisory group. On behalf of the RSB, I'd like to thank the representatives and others who have contributed their time and energy to UKPSF activities and we look forward to working with the people who will guide GARNet's future activities.

The UKPSF produces a monthly newsletter, rounding up policy news about plant science. You can subscribe to the newsletter and keep up to date with all our activities at rsb.org.uk/ukpsf.

Global Plant Council Update

Isabel Mendoza

GPC Communications Officer

isabel@globalplantcouncil.org

The Global Plant Council has continued working towards promoting plant science across borders and disciplines, by supporting those involved in plant science research, education, and training. In this way, we aim to increase awareness of the key contribution of plants and plant science to our society.

As you all well know, COVID19 has impaired our regular life postponing many conferences and events. The Global Plant Council's normal activities were impacted as well, forcing us to move our science communication workshop in Torino scheduled for the 30th of June.

Still, we haven't stopped promoting plant science online on our website and social media channels. Through them (Twitter, Facebook, and LinkedIn, Instagram…) we are currently reaching 21000 plant science enthusiasts.

The GPC website: http://globalplantcouncil.org/

As you may remember, last year, we announced the launch of our Early Career Researcher International Network (ECRi). The ECRi aims to help ECRs advance in their career by finding their next job or grant while helping them reach out to the community and beyond.

https://globalplantcouncil.org/ecri/

As mentioned, the network accommodates activities address to ECRs. Some of those activities focus on job hunting activities, such as the monthly #plantscijobs storm and the devoted Facebook and LinkedIn groups. We have also set up useful grants, jobs, and dissemination resources.

Recently, we partnered with the journal "Plants, People, Planet", and together we have launched our online #plantscivid video competition to give participants 1) the possibility to practice their science communications skills 2) while having the opportunity to win two $250 vouchers. We received 15 entries and the board is in the process of voting their favorites.

Please consider contacting Isabel Mendoza (isabel@globalplantcouncil.org), our Communications Officer with your suggestions. Any offers of help in rolling out the ECRi network are welcome! Additionally, we have set up a mailing list where ECRs can sign-in here.

https://twitter.com/GlobalPlantGPC

Introducing Arabidopsis Events UK

Over the past five years as GARNet Coordinator Dr Geraint Parry has led activities that have included meeting and workshop organisation, knowledge exchange and community integration. These activities have been overseen by the GARNet advisory committee and particularly by the leadership team of Professor Jim Murray and Professor Steven Spoel.

To manage GARNet's legacy Dr Parry aims to continue its activities by obtaining funding from other sources. He will be using the GARNet name but operating through a limited company 'Arabidopsis Events UK' https://arabidopsiseventsuk.weebly.com/

Dr Parry has an excellent knowledge of the landscape of UK plant science research community.

He aims to work across the UK plant science community so if you have any project ideas please get in contact!

Introducing Quantitative Plant Biology

Quantitative Plant Biology is a new open access journal, co-published by Cambridge University Press and The John Innes Centre with the aim of providing an interdisciplinary forum for high quality research on ground-breaking discoveries and predictions in quantitative plant science https://www.cambridge.org/core/journals/quantitative-plant-biology

The journal has a reputable editorial team with Olivier Hamant as Editor-in-Chief, 21 Associate Editors with expertise spanning the journal's scope, and Elliot Meyerowitz as Advisory Member.

Quantitative Plant Biology covers aspects such as:

- Multiscale (molecule to population) dynamics
- Variability, noise and stochasticity
- Nonlinearities and feedback loops
- Biochemical and mechanical signalling synergies
- Growth, patterning and developmental robustness
- Systems approaches for sustainability
- New theories and hypotheses

These questions can now be addressed thanks to quantitative approaches:

- Quantitative interactions and dynamics (systems biology approaches), e.g. molecular network dynamics and stochasticity, feedback mechanisms, cell biology, morphogenesis, physiology and morphodynamics

- Correlative data generating robust predictions (BigData approaches), e.g. co-expression analysis, deep-learning, statistical approaches to imaging and modelling (mathematical, statistical, computational) and ecosystem sustainability

- Large dataset resources (high throughput approaches), e.g. natural variation, (epi)genetics, "-omics", morphometry and biomechanics

Quantitative Plant Biology is now open for submissions, and welcomes papers at all biological scales (from molecular through cellular and organismal to populations) and from a wide range of sources (from lab to field). The journal also welcomes the submission of quantitative studies involving citizen science.

If you have any questions, please do get in touch with Alison Paskins (Publishing Editor for Quantitative Plant Biology at Cambridge University Press). axpaskins@cambridge.org

Dame Ottoline Leyser appointed new CEO of UK Research And Innovation (UKRI)

Professor Ottoline Leyser is a leading British plant biologist and Director of the Sainsbury Laboratory at the University of Cambridge. Starting the position on Monday 29 June, as UKRI CEO, Professor Leyser will guide the delivery on the government's ambitions to increase investment in research and development (R&D) to 2.4% of GDP by 2027, establishing the UK as a global hub for science and technology, now and far into the future.

This appointment will ensure the UK research sector remains at the forefront of new advances to tackle the biggest industrial and societal challenges affecting the world today including climate change, healthcare and the current coronavirus pandemic.

Business Secretary Alok Sharma said: '*Professor Leyser's appointment comes at a critical time for the UK. The coronavirus pandemic has shown the importance of science for our future and UKRI has a vital role to play in this. As the new Chief Executive, Professor Leyser will drive forward UKRI's mission to create the great British companies of the future and help keep the UK at the cutting edge of global research and development. I would like to thank Sir Mark Walport for his dedication to UKRI, leading its transformation programme and championing science, engineering and technology across the UK*'.

Professor Ottoline Leyser commented: '*UKRI has a unique opportunity to make a profound contribution to tackling the many challenges facing the world. During my career, I have seen the power of genuinely collaborative cultures to catalyse the transformative thinking needed to create effective solutions. I look forward to working with the UKRI team to ensure that the UK's superb research and innovation system continues to work for everyone, by pioneering new partnerships, developing innovative funding models and strengthening international collaboration*'.

https://www.gov.uk/government/news/dame-ottoline-leyser-appointed-new-ceo-of-uk-research-and-innovation-ukri

The GARNet community is delighted that the first GARNet PI from back in 2000 has now taken on the highestt position in UK Publically funded Science. *At the very least this will ensure that Plant Science is not a forgotten area of research!*

Conference Update

This has been a challenging time for both conference organisers and conference venues. Most 2020 plant science conferences have cancelled or postponed.

Below is a non-exhaustive list of the changes that have been made to these conferences. Up to date as July 29th 2020.

International Conference on Arabidopsis Research (ICAR)

The organisers of the ICAR2020, ICAR2021 and ICAR2022 meetings got together and agreed to move each of their conferences forward a year. This was possible due to the excellent international collaboration across the Arabidopsis community.

Although ICAR meetings are advised by the Multinational Arabidopsis Steering Committee (MASC) each ICAR is a stand-alone meeting that does not receive any support from a learned society (or similar). Each meeting is run as a not-for-profit event!

ICAR2021 Seattle, USA: *June 21st-25th 2021*
http://icar2020.arabidopsisresearch.org/
ICAR2022 Belfast, UK: *June 20th-24th 2022*
http://icar2022.arabidopsisresearch.org/
ICAR2023: Chiba, Japan: *June 5th-9th 2023*

Society of Experimental Botany (SEB)

SEB were forced to cancel their 2020 meeting in Prague. Each session organiser has been given the option of transferring their session to the 2021 event in Antwerp, Belgium. However SEB have also selected a new set of sessions to complement those already planned.

SEB 2021, Antwerp: *June 29th-June 2nd 2021*
https://www.sebiology.org/events/event/seb-antwerp-2021
SEB 2022, Marseille: *Dates tbc*

Plant Biology Europe 2020

This event has been postponed until June 2021.

PBE2020, Turin: *June 28th -July 1st 2021*.
https://europlantbiology2020.org/

Auxin2021

The four-yearly Auxin workshop was scheduled for October 2020 but the organisers have taken the difficult decision to move this event to October 2021.

Auxin2021, Croatia: *October 3rd-8th 2021*
https://auxin2020.weebly.com/

International Congress on Plant Molecular Biology

This event remains scheduled for October 2021.

IPMB2021: Cairns, Australia:
October 24th-28th 2021
https://ipmb2021.org/

Genetics Society Arabidopsis meeting

This meeting has been postponed from 2020 to similar dates in 2021 and remains at Durham University

GenSoc Arabidopsis Meeting, Durham University: *April 20th-21st 2021*
https://genetics.org.uk/events/arabidopsis/

Monogram 2021

The 2020 meeting was scheduled for Dundee but has now been postponed until 2021.

Monogram2021, Dundee: *April 27th-29th 2021*
https://ics.hutton.ac.uk/monogram20/

EMBO Workshop

This 2020 meeting scheduled for the University of St Andrews has been postponed until 2021.

EMBO Workshop on Intercellular communication and plasmodesmata in plant development and disease St Andrews: *July 11th-16th 2021*
https://meetings.embo.org/event/20-plant-intercellular-communication

American Society of Plant Biologists (ASPB)

At time of writing the Plant Biology Worldwide Summit is taking place online. This five-day event will have 10.5 hours of virtual content each day across plenary and concurrent sessions! It will be fascinating to learn about the virtual attendance for this event as it will inform us about the future of international conferences for the plant science community.

ASPB hopes to return to a live meeting in 2021
Plant Biology 2021 – Pittsburgh, PA: July17th-21th
https://aspb.org/meetings-events/

PB20 PLANT BIOLOGY
JULY 27 - 31 | WORLDWIDE SUMMIT

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GARNish
Bacterial Plant Diseases Programme

Introducing Strategic Priorities Fund 'Bacterial Plant Diseases Programme'

UKRI-BBSRC, UKRI-NERC, DEFRA and the Scottish Government have come together to support high quality multidisciplinary research projects through the Strategic Priorities Fund under the umbrella of the '**Bacterial Plant Diseases Programme**'. These projects aim to understand the complex interactions between bacterial pathogens of UK plants, their hosts, the vectors that transmit them, and the wider environment. https://www.bacterialplantdiseases.uk

Phase I of this project commissioned the BRIGIT project, which brings together a broad group of experts to investigate multiple challenges presented by the emerging threat of *Xylella fastidiosa*.
https://www.jic.ac.uk/brigit/

Phase 2 has provided £15M to support a further eight projects in this research area. Most projects focus on investigating the bacterial determinants of plant disease but will also feed into future agricultural benefits.

The funders have also recruited a Project Coordination Team (CT) that will identify synergies between projects and their potential external stakeholders. The CT will arrange training opportunities relevant for all projects as well as ensure that the resulting data is findable, shareable and reusable. The CT will promote these activities through a website, social media (@BactPlantDis) and other sources of multimedia. The CT concept is a new venture for UKRI so it will be fascinating to discover how it works and whether it can be replicated to manage linkages between projects in other areas of research.

The CT is led by Sarah Green and Mariella Marzano at Forest Research, Murray Grant at the University of Warwick and Joana Vicente at Fera, whose mix of expertise will integrate with an expert advisory panel to maximise the outreach, scientific and impact outputs from the BPD projects. Additional stakeholder engagement, community integration and project support will be provided by Laura Meagher, Geraint Parry and Debbie Frederickson-Matika.

The eight Phase 2 projects begin in summer 2020 and their details are below:

Lead PI: Duncan Cameron, University of Sheffield
Title: Harnessing and integrating disease suppressive microbes and synthetic soils for sustainable, low input horticulture
Description: Investigate the microbiome that characterises disease-suppressive soils and look to develop synthetic growth materials for sustainable farming.

Lead PI: Sandra Denham, Forest Research
Title: BAC-STOP: Advancement of control and knowledge to save threatened oak and protect them for future generations
Description: Investigate the microbial and vector biology as well as the community impact of Acute Oak Decline

Lead PI: Adrian Fox, Fera Science
Title: Benign infections or damaging epidemics: the influence of biology, the environment and agricultural practice on vector-borne phytobacteria (CALIBER)
Description: Understand the biology and societal impact of the insect vectors of *Candidatus Liberibacter solanacearum*.

Lead PI: Ville-Petri Friman, University of York
Title: Using phages as a precision tool to control pathogen abundance and virulence in the plant rhizosphere microbiome
Description: Investigate the potential of phage therapy to tackle the tomato pathogen *Ralstonia solanacearum*

Lead PI: Murray Grant, University of Warwick
Title: Xanthomonas plant diseases: mitigating existing, emerging and future threats to UK agriculture
Description: Utilise extensive Brassica germplasm to investigate the genetics, demography and diagnosis of *Xanthomonas* spp

Lead PI: Richard Harrison, NIAB Cambridge Crop Research
Title: Predicting the emergence of host adapted plant pathogens: *Pseudomonas-Prunus* system
Description: Take a multidisciplinary approach to investigate the interactions between *Pseudomonas* spp and bacterial canker of UK cherry trees

Lead PI: James McDonald, Bangor University
Title: Future Oak: Characterising and engineering the oak microbiome to future-proof an arboreal icon
Description: Investigating the role of the disease suppressive microbiome in oak trees

Lead PI: Ian Toth, James Hutton Institute
Title: Building a decision support tool for potato blackleg disease (DeS-BL)
Description: Investigate the relationship between *Pectobacterium atrosepticum* and nematode vectors in the spread of blackleg disease of potato

If you have any questions about these projects then please contact the CT through project website and they will work with you to maximise your interaction!

https://www.bacterialplantdiseases.uk

Crop Health & Protection (CHAP)

Darren Hassall
Head of Marketing

https://chap-solutions.co.uk/

Funded by Innovate UK, the primary aim of CHAP (Crop Health & Protection) is to understand industry challenges, drive research and innovation and develop and trial solutions to transform agriculture.

The global food system is facing a plethora of challenges, including providing safe and nutritious food to a growing population in a manner that minimises its impact on the environment while reducing its inputs. Layered on top of this are the pressures from climate change, changing consumer habits, and the ability for the grower to deal with the natural world that agricultural works alongside – plants, pests and diseases which continue to pose a threat to crop production.

Generating solutions to these problems will require new approaches, the adoption of cutting-edge technologies and collaboration across the agricultural sector and beyond. Recognising this need, in 2016, the Government-funded the formation of four UK Agri-Tech Centres for Innovation. CIEL covers livestock, Agri-EPI has a focus on precision approaches, and Agrimetrics specialises in data.

https://www.agritechcentres.com/

At Crop Health and Protection, as our name suggests, we have a remit to advance crop productivity in a sustainable manner for future generations. We do this by acting as a nexus between government, scientists, farmers, advisers, innovators and industry, bringing together experts to develop innovative and transformative solutions to bottlenecks and barriers across the sector.

Our Strategy

By leveraging funding from the UK's innovation agency, Innovate UK and working with our partners we have developed and built open access, state-of-the-art facilities, run by world-class experts, that provide cutting edge research capabilities which are available to all to drive forward research and innovation and develop and trial solutions to transform agriculture.

These include facilities in key areas of crop protection, soil health, data and diagnostics, and controlled environment agriculture (CEA).

Crop Protection

https://chap-solutions.co.uk/solutions/crop-protection/

The number and types of products available to growers to combat pests and disease is reducing due to environmental and management pressure, emerging resistance, tightening regulation and cost of production. The situation is already critical with several pest, weed and disease problems having few or no effective solutions eg black grass and cabbage steam flea beetle.

To help support the sector CHAP has number of facilities more details of which can be found here:

- E-Flows Mesocosm
- Advanced Glasshouse Facility
- Fungal Biopesticide Development Lab
- Molecular Diagnostic Laboratory
- National Reference Collection
- Fine Phenotyping Laboratory

Soil Health

https://chap-solutions.co.uk/solutions/soil-health/

Soils are a key and often under-valued resource in agriculture which are under constant pressure from the environment (erosion) and the grower (reduced fertility). To help understand and manage our soils in a more productive and sustainable way CHAP has a range of facilities including:

- Phenotyping and Soil Health Facility
- Field Scale Precision Equipment

Data and Diagnostics

https://chap-solutions.co.uk/solutions/data-diagnostic-insights/

Advances in remote sensing and diagnostic technology provide a wealth of data which can be used to predict crop growth and more importantly the pest and disease pressure. CHAP's facilities include:

- Crop Monitor Pro

- International Pest Horizon Scanning

- Lab to Field (Mobile Crop Science Labs

Controlled Environment Agriculture

https://chap-solutions.co.uk/solutions/controlled-environment-agriculture/

Farmers and growers are constantly looking to increase both yield and quality while maximising gross margins in a sustainable manner. Controlled environment such as greenhouse and vertical farming systems provide one potential mechanism to producing food in a more sustainable manner with fewer inputs.

CHAP is working with innovators across the industry to analyse and assess new approaches and technologies in this sector via its commercial demonstrators:

- Vertical Farming Development Centre

- Innovation Hub for Controlled Environment Agriculture

- Natural Light Growing Centre

- Crop Storage Research Facility

Our Network

https://chap-solutions.co.uk/our-network/

CHAP has a wide network of partners including key businesses working across the agricultural, scientific research, retail and academic sectors. We work with our partners and the wider community to design and implement multi-disciplinary projects that tackle major intractable problems across the agriculture and food systems.

CHAP also has a growing membership scheme, which is available to all, from new-

tech start-ups including Small Robot Company and Hummingbird Technologies to blue-chip organisations such as McCain. Via our partners and members, we aim to develop networks that stimulate new opportunities for collaboration, innovation and business, and provide a platform for knowledge exchange.

Despite its comparative youth, CHAP has laid down strong roots for the future. Working with our partners and members we have already developed a number of ambitious projects including one to develop a diagnostic tool for potato cyst nematode (PCN) in Kenya, in partnership with CHAP member PES Technologies and Kenyan research organisation icipe. In the UK we are partnering with Liberty Produce and several other partners on a project to increase the commercial viability of vertical farming systems, improving yields by 30 per cent and cutting operational costs by 25 per cent.

A number of our members, including start up pioneers Small Robot Company (https://www.smallrobotcompany.com/) and crop analytic artificial intelligence pioneer Hummingbird Technologies (https://hummingbirdtech.com/) have already hit the headlines for all the right reasons, and CHAP will continue to provide a forum for researchers and innovators of the future.

Farming has always been an arduous (sometimes back breaking) and complex business. In providing food and numerous other products for us all to consume and use, today's growers must deal not only with local challenges such as pests, disease and soil health but also global challenges of climate change, commodity markets and international policy.

CHAP is proud to be playing a key role in supporting the sector by working in partnership with a range of stakeholders to develop, test and promote agri-tech innovations that will ensure the UK is at the forefront of meeting the need to feed and support a growing world population while preserving the earth's vital natural resources.

A Potted History of GARNet

After twenty successful years we are disappointed that funding for the Genomic Arabidopsis Resource Network (GARNet) will not be renewed by UKRI-BBSRC. Two attempts were made to secure funding via Responsive Mode but Panel B decided that it was not the time to support a network grant of this type.

There is no doubt that a network grant is a difficult fit for Responsive mode funding, the aim of which is to rightly support world-leading bioscience. We hope that future discussions might lead to a different mechanism through which community-facing research networks may be funded through UKRI.

Despite this disappointment we are very proud of all that GARNet has achieved over the past twenty years and we are hopeful that future plant science research networks can benefit from the legacy of GARNet activities.

The current GARNet leadership team will continue activities to promote excellence in UK plant science and to provide training opportunities for the community. They are also exploring funding mechanisms that may allow an expansion of these activities in order to integrate the technological developments that link different areas of the UK plant science community.

The History of GARNet

Following the publication of the Arabidopsis genome in 2000 and to take advantage of the rapidly increasing set of its molecular tools, Ottoline Leyser, then based at the University of York, led a successful bid to the BBSRC Investigating Gene Function (IGF) initiative to establish the Genomic Arabidopsis Resource Network (GARNet). The four-year project was led from York, coordinated by Ottoline and Karin Van de Sande whilst the activities were overseen by an academic advisory group. The aim of GARNet was to provide reliable, user-driven and publicly available functional genomic resources for Arabidopsis researchers.

During this first phase of funding, GARNet facilitated the set up of transcriptomic, bioinformatic (both at Nottingham), proteomic (Cambridge) and metabolomic (Rothamsted) facilities as well as provision for the generation of mutant populations and clones at the John Innes Centre. In addition GARNet hosted a successful annual meeting, the first of which was attended by 250 delegates in 2000.

After four productive years of facilitating the adoption of functional genomics, the role of GARNet was revised to support the emergence of systems biology as a tool for network analysis and gene discovery. During this period GARNet activities were led from the University of Edinburgh by Andrew Millar as PI and Ruth Bastow as the full time coordinator.

This technological foresight was further demonstrated as GARNet was funded by BBSRC for another five years (2010-2014) with Jim Beynon at the University of Warwick as PI and Ruth Bastow, Irene Lavagi, Charis Cook and Lisa Martin as the coordination team. On this occasion the proposal explored the use of synthetic biology in plant science, helped expand the uptake of systems biology approaches, promoted translational research as well as supported the international community through administration of the Multinational Arabidopsis Steering Committee (MASC).

The linkages between GARNet and the wider UK plant science community were

GARNish
Twenty Years of GARNet

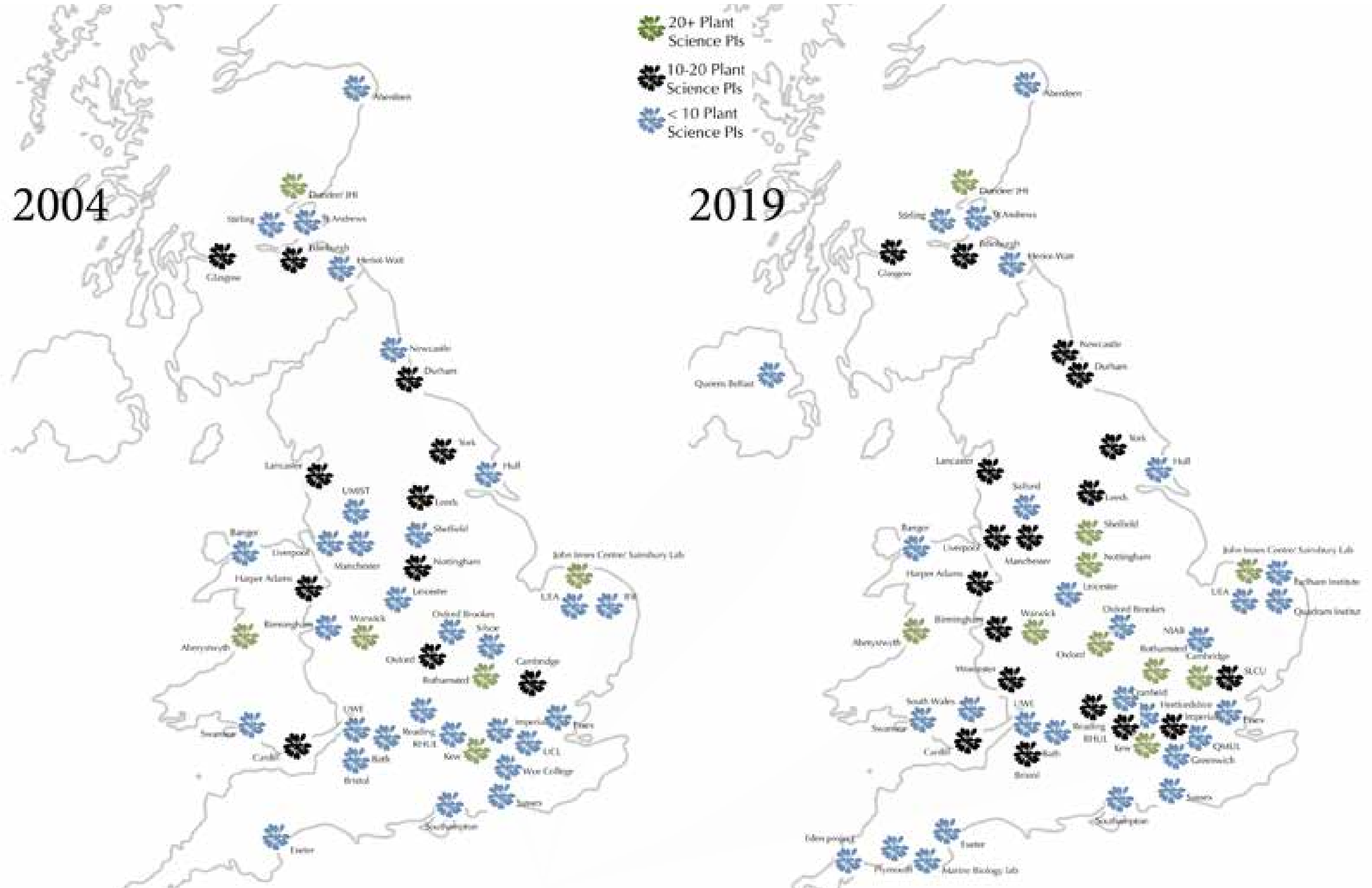


Figure 1: UK Plant Science in 2004 and 2019. Data for 2004 was taken from Edition one of the GARNish newsletter and may exclude PIs from departments that focus on more ap-plied research. Data for 2019 was taken from prior knowledge and online searches.

expanded during a fourth round of BBSRC funding between 2015-2020. In this period GARNet promoted the use of new technologies that were relevant for all plant scientists in order to facilitate the translation of ideas from models to crops.

These activities had a particular focus on gene editing and also on establishing the software and hardware infrastructures needed to deal with big data. This final UKRI-BBSRC funded iteration of GARNet activities was led by Jim Murray at Cardiff University with Geraint Parry as the full time coordinator with support from Ruth Bastow and Lisa Martin.

How has UK plant science changed since 2004

The past two decades have brought a radical transformation in the ways plant science research is conducted, including the increasingly pivotal role of data science skills, the integration of molecular analysis with developmental, evolutionary and environmental insights, and the translational advances in applied crop science.

Over the same period, many although not all, exclusively botanical or plant-science focused degree programs have disappeared from UK higher education (Drea (2011 The End of the Botany Degree in the UK, Bioscience Education, 17:1, 1-7, DOI: 10.3108/beej.17.2). Nevertheless, it appears that the size of the UK plant science

Name	Institution	Starting year on GARNet Advisory Committee
John Doonan	Aberstywyth University	2012
Jim Murray	Cardiff University	2011
Colin Turnbull	Imperial College	2017
Robert Sablowski	John Innes Centre	2009
Saskia Hogenhout		2015
Smita Kurup	Rothamsted Research	2011
Alessandra Devoto	Royal Holloway University of London	2009
Jonathan Jones	Sainsbury Lab, Norwich	2005
Cyril Zipfel		2012
David Salt	University of Aberdeen	2013
Julia Coates	University of Birmingham	2010
Daniel Gibbs		2016
Claire Grierson	University of Bristol	2005
Antony Dodd		2013
Jill Harrison		2016
Ian Furner	University of Cambridge	2000
Paul Dupree		2006
Alex Webb		2009
Ian Henderson		2014
Phil White	University of Dundee, James Hutton Institute	2007
Claire Halpin		2008
Sarah McKim		2017
Keith Lindsey	University of Durham	2000
Patrick Hussey		2008
Heather Knight		2012
Andrew Millar	University of Edinburgh	2000
Steven Spoel		2015
Christine Raines	University of Essex	2015
Sabina Leonelli	University of Exeter	2009
Nick Smirnoff		2010
Anna Amtmann	University of Glasgow	2008
Eirini Kaiserli		2018
Phil Gilmartin	University of Leeds	2000
Brendan Davis		2006
Stefan Kepinski		2009
Yoselin Benitez-Alfonso		2018
Anthony Hall	University of Liverpool	2012
Simon Turner	University of Manchester	2000
Sean May	University of Nottingham	2000
Zoe Wilson		2006
Malcolm Bennett		2011
Zoe Wilson		2014
Nick Harberd	University of Oxford	2000
Miltos Tsiantis		2007
Ian Moore		2010
Nick Harberd		2013
Renier Van Der Hoorn		2018
Julie Gray	University of Sheffield	2005
Jim Beynon	University of Warwick	2007
Katherine Denby		2014
Murray Grant		2016
Ottoline Leyser	University of York	2000
Andrea Harper		2017
Murray Grant	Wye College	2000

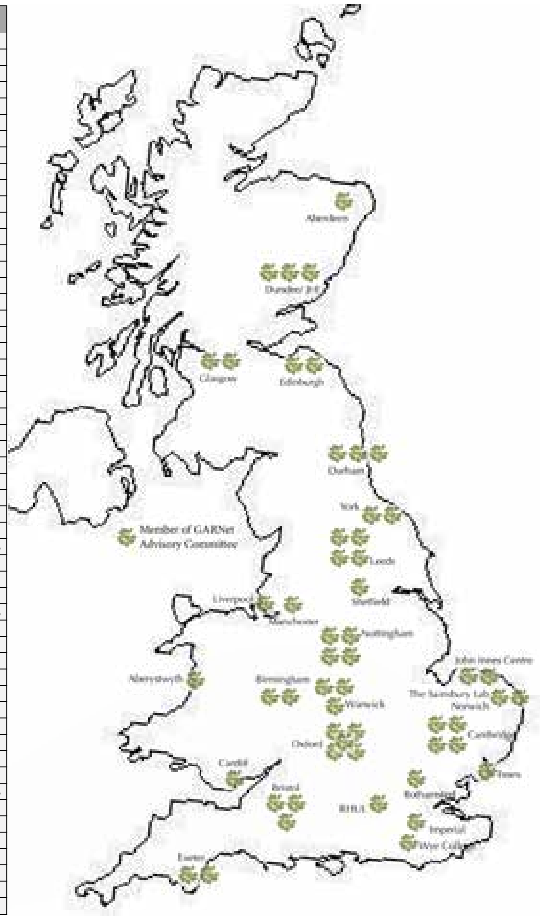


Figure 2: List of members of the GARNet Advisory Committee between 2000-2019 and their locations across the UK

research community has found a way to at the very least remain stable.

In the first edition of the GARNish newsletter in 2004, then coordinator Ruth Bastow collated a map of plant science activities across the UK. Although we don't have the data that generated this 2004 figure we think that institutions with more applied or botanical research might have been under represented (Figure 1).

However when 2019 is compared to 2004, it appears that the number of UK plant science PIs has most likely grown. Most notably are the departments in Sheffield and Nottingham (featured in the Spotlight article in this edition of GARNish) that now have a much larger number of PIs. This also is includes the inauguration of the Sainsbury lab, Cambridge University (SLCU) and the expansion of academic plant science cohorts such as those in Birmingham, Bristol, Cardiff, Manchester and Newcastle.

Over the past twenty years 51 academics have sat on the GARNet advisory committee. 37% of these academics are female and whilst this is not perfect we feel that over 20 years it represents a commitment to equality. Committee members have a wide geographic spread ensuring that they represent the entire academic community and are not focused on the centres of plant science excellence (**Figure 2**). Furthermore GARNet's commitment to the future of UK plant science is highlighted by the regular involvement of early career faculty members on the advisory committee. Since 2014, eight of the fifteen elected members have been within the first eight years in an academic position.

Some of the past GARNet advisory committee members have kindly provided their reflections on the news that BBSRC GARNet funding is ending:

Ottoline Leyser, Sainsbury lab, Cambridge University and current UKRI-CEO.

'It's rather difficult to come up with a one-liner on 20 years of GARNet! Here are some thoughts. The UK Plant Science community was both brought together and galvanised by the AFRC/BBSRC Arabidopsis initiatives, led from the John Innes Centre in the 1990s. GARNet very much grew out of the success of that effort, providing functional genomics resources in a community-centred way. The success of both Arabidopsis and post-genomic technologies has made a much wider range of plants are accessible to analysis, unleashing the power of comparative approaches, and catalysing translation in a wide range of domains. The challenge for the community now is to retain the benefits of a community-oriented approach in a much more disparate plant science research landscape'.

Malcolm Bennett, University of Nottingham

'GARNet has played a vital part over the past 20 years creating an integrated UK Plant Science community, coordinating the development of world-leading tools, technologies, services and training, and more recently championing the science outputs of all UK-based ECRs to established scientists. It is a legacy all of the GARNet community should be very proud of'

Juliet Coates, University of Birmingham

'Really sorry to hear about the demise of GARNet (in its current form- Ed). We will lose the sense of a cohesive community that gives Arabidopsis researchers a clear, collective voice interfacing constructively with funders and collaborating with other plant science researchers in the UK and worldwide'.

Katherine Denby, University of York

'I think GARNet provided a critical community building role within UK plant science. I particularly enjoyed the plant-focused meetings with an emphasis on new technologies that can be applied across species. Played a key role in broadening awareness and uptake of new technologies.

Keith Lindsay, University of Durham

'GARNet was a fantastic mechanism to build a plant science community in the UK, very important in particular for ECRs, and I'd hope something can replace it - there is a need!'

Antony Dodd, John Innes Centre

'GARNet has built the modern basic plant sciences research community'

Jill Harrison, University of Bristol

'For me the workshops supporting novel technologies are the things that stand out most'.

The GARNet leadership team would like to thank everyone who has contributed to its activities either by sitting on the advisory committee, participating in training workshops or presenting their research at our conferences as well as the delegates who attended our events or anyone who has liked our social media posts!

It's the end of this era of GARNet but onto the next incarnation!

> Use the resources outlined on the GARNet website:
https://www.garnetcommunity.org.uk/
> Read the GARNet blog:
http://blog.garnetcommunity.org.uk/
> Listen to the GARNet podcast:
http://blog.garnetcommunity.org.uk/garnet-community-podcast/
> Watch the #GARNetPresents webinar series:
http://blog.garnetcommunity.org.uk/garnet-presents-webinars/

Reviewing the GARNet Research Roundup

http://blog.garnetcommunity.org.uk/

During the fourth round of successful GARNet funding (2015-2020) we produced the semi-regular GARNet Research Roundup (GRR). These blogposts highlighted publications in peer-reviewed journals that included a contribution from UK-based researchers.

Between 2015-2018 the highlighted publications included research mostly performed in Arabidopsis but more recently the GRR has included discovery-led research performed in any plant species (the GRR switched from 'Arabidopsis Research Roundup' to the 'GARNet Research Roundup' in March 2018).

The GARNet remit is to support researchers performing discovery-led research so the GRR doesn't highlight more applied research. Therefore the contributions of departments and/or PIs that focus on applied research would have been under represented in the GRR articles.

The GRR only includes original research in peer-reviewed publications and so does not include review articles or preprints. The papers were identified through PubCrawler update alert software, which searches publications archived on NCBI PubMed (pubcrawler.gen.tcd.ie/) as well as through individual searches and our knowledge of community activities.

From May 2015 until June 2020, 884 papers have featured in the GRR. In comparison between 2015-2020 a PubMed search using the following terms (Arabidopsis[Title/Abstract] AND UK AND ("journal article"[Publication

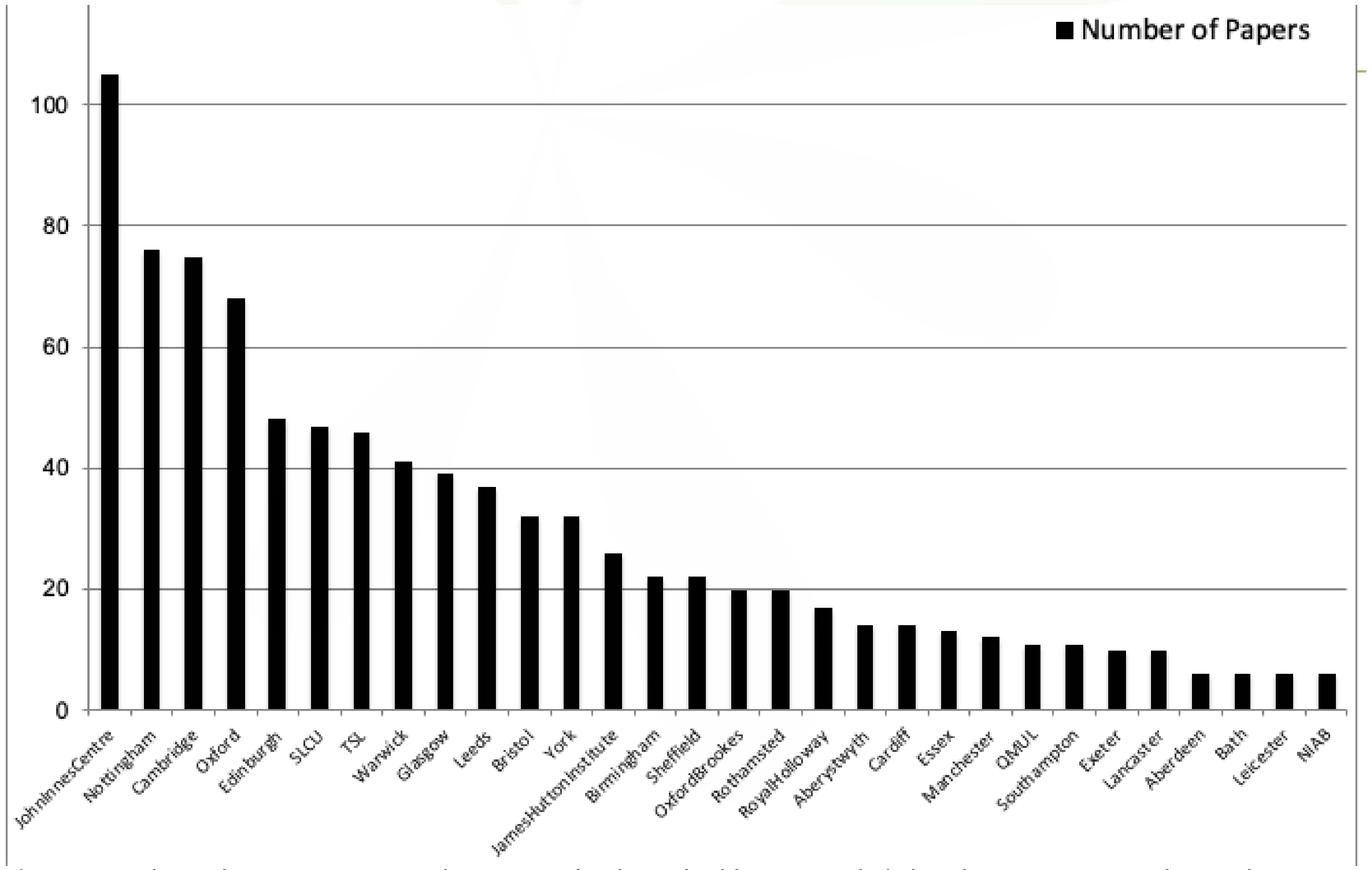


Figure 1: Academic department or Research Institutes of authors of publications included on the GARNet Research Roundup between May 2015- June 2020. We include departments/ institutes with >5 papers featured in the GRR.

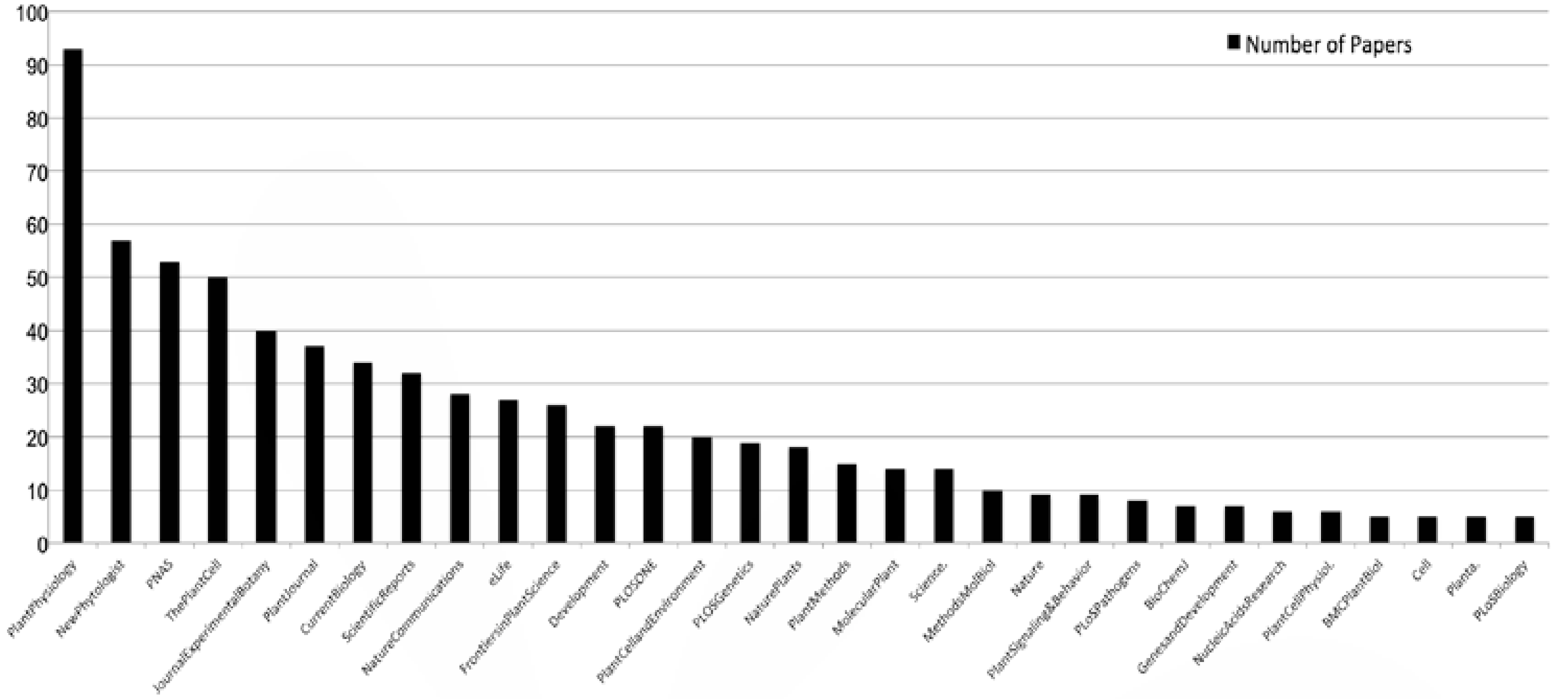


Figure 2: Journals of publications included on the GARNet Research Roundup between May 2015- June 2020. We include journals that have > 4 papers in the GRR.

Type]) AND 2015(2016 etc) [DP]) identified 1389 published papers. Therefore the GRR does not highlight all papers but we do feel that we will have documented a higher majority of those papers for which UK-based researchers were the first or corresponding author(s). We understand that research is a global collaborative pursuit but have focused on the UK since GARNet is funded through UKRI-BBSRC.

We analysed the papers featured in the GARNet Research Roundup on the basis of the authors academic department or institution (**Figure 1**). We find that 45 departments/institutes have published manuscripts that have featured in these articles. When we compare the publication list with a map of UK plant science departments (see page 15) we can see that institutions with the largest plant science departments have the highest number of publications (John Innes Centre, Nottingham, Cambridge and Oxford). Edinburgh and the two Sainsbury labs (SLCU at Cambridge. TSL at Norwich) have a smaller number of PIs yet have also published a high number of papers.

Some larger departments with less paper featured in the GRR likely reflects that they have a focus on research areas other than discovery-led science (e.g. James Hutton Institute, Aberystwyth, Rothamsted, Kew Science).

We also looked at the journals in which manuscripts that feature in the GARNet Research Roundup were published (**Figure 2**). Plant Physiology is the largest plant science focused journal, ordinarily publishing >25 research papers per month. Therefore it is no big surprise that papers from this journal have been featured the most times in the GRR. Other plant science-specific journals such as New Phytologist, The Plant Journal, Journal of Experimental Botany and The Plant Cell often featured in 'GRR papers'.

The GRR has featured 29 papers from Cell-Nature-Science (CNS) journals (6-9-14 respectively). Fifteen of these papers have been led by UK-based scientists, including 4 from the John Innes Centre, 3 from The Sainsbury Lab, Norwich, 2 from The Sainsbury Lab Cambridge University and one each from Birmingham, Glasgow, Manchester, Nottingham/Durham, Oxford and York.

Update taken from the Multinational Arabidopsis Steering Committee Annual Report

http://arabidopsisresearch.org/images/publications/mascreports/MASC_Report_2020_Online_.pdf

The 2019 MASC Annual Report reported for the first time that the number of publications that included Arabidopsis had slipped below those publications that included rice. This trend continues the 2020 report as the number of rice publications move further ahead of those that include 'Arabidopsis'. (**Figure 1**)

The number of Arabidopsis publications has plateaued since 2013 and with current trends will be soon overtaken by the number of publications that include maize/corn or wheat/Triticum. We speculated last year that this represents a general global change in emphasis from discovery-led to more applied plant science research and that the progress that has been made with Arabidopsis has been transitioned to other plant species. However thse trends are undoubtedly also linked to technical improvements that has made analysis of more complex genotypes and phenotypes more routine.

Despite the plateau in the number of papers containing 'Arabidopsis' China continues to buck-the-trend with 2019 seeing a continuing increase in its number of publications (**Figure 2**). The other four nations with the highest number of publications remain the same as in 2018 as the number of their outputs have levelled. A significant positive conclusion to be drawn from Figures 1+2 is that the numbers have not declined over the past five years, so perhaps the amount of global Arabidopsis research has reached a status-quo.

Figure 3 shows the proportional changes in the number of Arabidopsis publications between 2011 and 2019 for the 30 countries included in the 2020 MASC report. Between 2011 and 2015

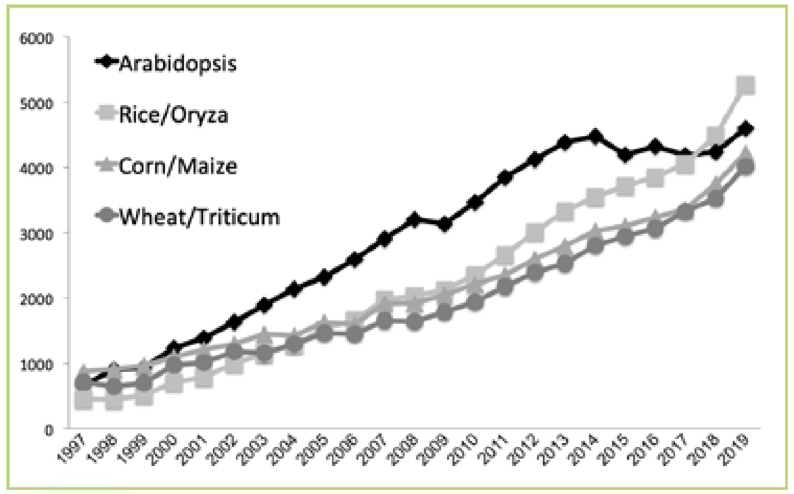


Figure 1: Papers published in Pubmed journals globally with Arabidopsis, rice/oryza, corn/maize or wheat/triticum in the Title/Abstract.

27 of 29 countries showed an increase in the number of their Arabidopsis publications (Figure 3, any green colour) whilst 7 of these increases were greater than two-fold (**Figure 3**, darkest green).

However between 2015 and 2019 the number of countries with an increase was 22 of 30, with just 2 of these with the higher increase (**Figure 3**, darkest green). This reduction in number of countries that have higher increases in the number of Arabidopsis publications corresponds to the plateau in the overall number of publications (**Figure 1**).

In 2019 many "Cell-Nature-Science" (CNS) publications featured Arabidopsis research, documenting a number of firsts in plant science. These include the discovery in plant nuclei of liquid–liquid phase separations of polyadenylation complexes [1], defining the control and

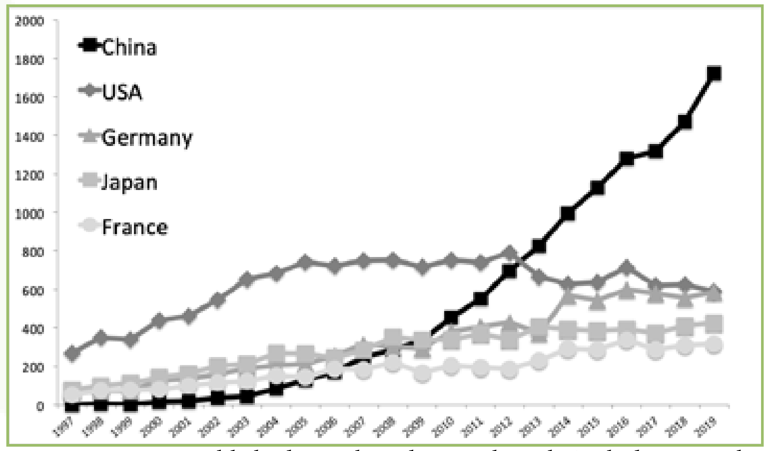


Figure 2: Papers published in Pubmed journals with Arabidopsis in the Title/Abstract since 2011. Globally These countries are have the highest number of publications.

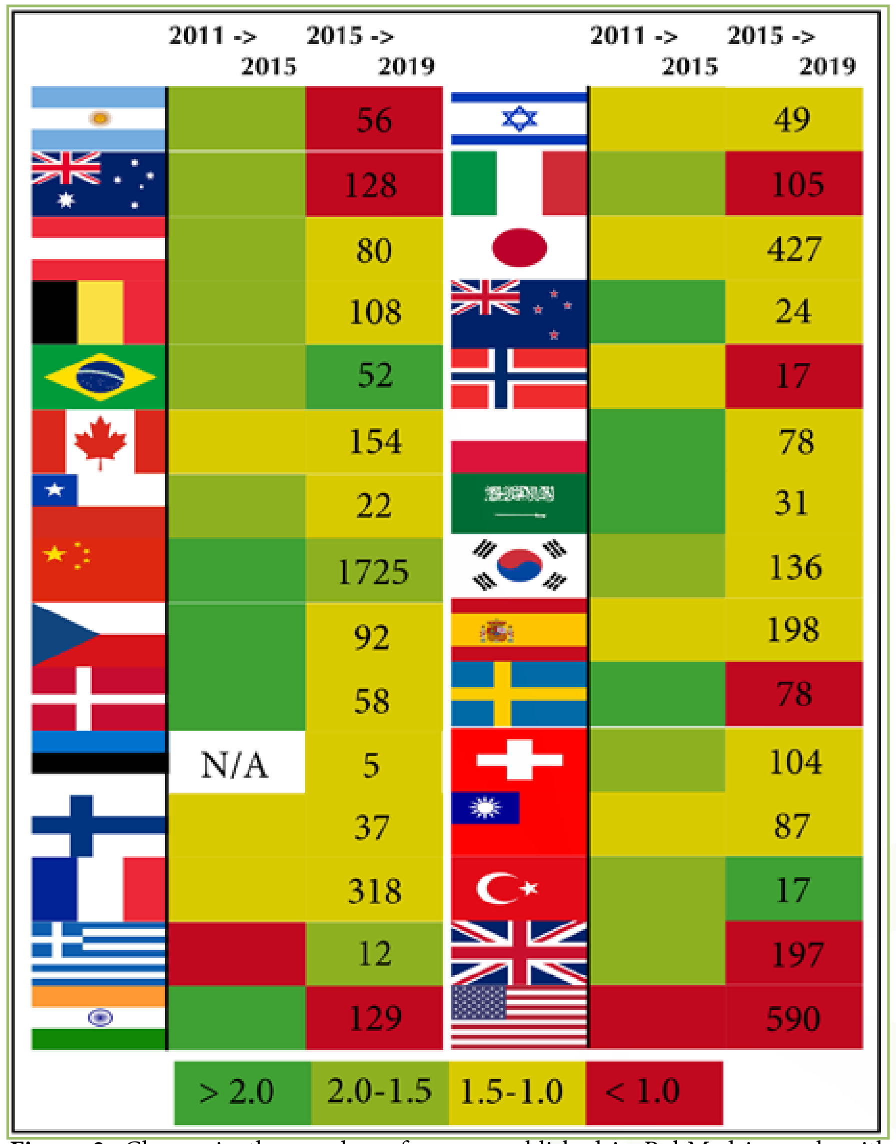


Figure 3: Change in the number of papers published in PubMed journals with Arabidopsis in the Title/Abstract between 2011 and 2015 or between 2015 and 2019. Countries are those included in this report. The proportional change in the number of publications between years are colour-coded as follows: Dark green (>2.0), Green (1.5 – 2.0), Lime Green (1.5 – 1.0), Red (<1.0). The following terms were used in the PubMed search box: Arabidopsis[Title/Abstract] AND COUNTRY AND ("journal article"[Publication Type] OR "review"[Publication Type]) AND YEAR[DP]. The number of publications in 2019 is documented in the right-hand box.

organization of the cambial stem cells that are the pregenitors of all woody tissues [2], identifying molecular controls of autophagy [3], engineering a synthetic switch for control of stomatal opening [4] or defining the first complete blueprint for immunity pan-NLRomes [5].

This breadth of topics covered across CNS publications shows that research in Arabidopsis continues to be influential in many areas of plant science (**Figure 4**). There is no assumption that CNS papers are of higher quality than those published elsewhere and their success and longevity will be judged in the fullness of time.

Importantly the corresponding authorship of the 2019 CNS papers are spread around the globe with 13 led from Europe, 7 from the USA and 5 from China, although of course most of these papers are cross-border collaborations.

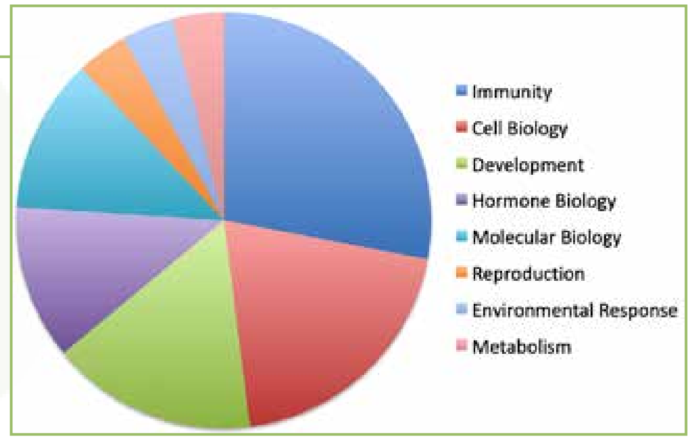


Figure 4: Broad categories of 2019 Cell-Nature-Science publications that feature research performed in Arabidopsis

[1]- Fang, X., Wang, L., Ishikawa, R. et al . Arabidopsis FLL2 promotes liquid–liquid phase separation of polyadenylation complexes. Nature 569, 265–269 (2019). doi:10.1038/s41586-019-1165-8

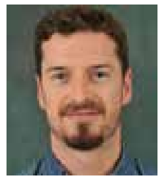
[2]- Miyashima, S., Roszak, P., Sevilem, I. et al . Mobile PEAR transcription factors integrate positional cues to prime cambial growth. Nature 565, 490–494 (2019). doi: 10.1038/s41586-018-0839-y

[3]- Marshall RS, Hua Z, Mali S, McLoughlin F, Vierstra RD. ATG8-Binding UIM Proteins Define a New Class of Autophagy Adaptors and Receptors. Cell. ;177(3):766-781.e24. doi: 10.1016/j.cell.2019.02.009

[4]- Papanatsiou M, Petersen J, Henderson L, Wang Y, Christie JM, Blatt MR. Optogenetic manipulation of stomatal kinetics improves carbon assimilation, water use, and growth. Science. 363(6434):1456-1459. doi: 10.1126/science.aaw0046

[5]- Van de Weyer AL, Monteiro F, Furzer OJ, Nishimura MT, Cevik V, Witek K, Jones JDG, Dangl JL, Weigel D, Bemm F. A Species-Wide Inventory of NLR Genes and Alleles in Arabidopsis thaliana. Cell. 178(5):1260-1272.e14.

Plant RNA-interactome capture (ptRIC), a new approach to discover RNA-binding proteins from plant leaves



Marcel Bach-Pages
University of Oxford
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The development of plant RNA-interactome capture (ptRIC) has been possible thanks to a collaborative effort between the lab of Gail Preston (Dept. Plant Sciences) and Alfredo Castello (Dept. Biochemistry) at the University of Oxford.

Why we developed ptRIC?

RNA-binding proteins (RBPs) have attracted much attention in the last decades due to their essential roles at controlling RNA fate and their participation at virtually every stage of RNA life cycle. Hence, RBPs are critical for gene expression and, therefore, for the cell and its adaptation to the everchanging environment.

Until recently, our knowledge on RBPs was limited as we lacked methods to systematically identify RBPs in vivo. In 2012, a new approach for comprehensive discovery of RBPs in living cells was developed and was named 'RNA interactome capture' (RIC) (Castello et al. 2012, Cell). RIC uses UV light to crosslink proteins that are in intimate contact with RNA, followed by capture and identification of poly(A) RNA – RBP complexes using oligo(dT) beads and quantitative proteomics. Since its development in human cells, RIC has been adapted to several organisms including yeast, worm, fly, zebrafish and mouse.

It wasn't until 2016 when RIC was first successfully applied to different tissues of Arabidopsis thaliana (etiolated seedlings, cell cultures and protoplasts; Reichel et al. 2016, Plant Cell; Marondedze et al. 2016, Sci. Rep; Zhang et al. 2016, Plant Methods). However, none of the studies successfully applied RIC to Arabidopsis leaves, since plant leaves impose different technical challenges. For example, the thickness of the leaves and their UV-absorbing pigments such as chlorophyll challenges the critical UV-crosslinking step. However, the need to study RBP dynamics in physiologically relevant plant tissues called for further developments.

The advent of plant RNA interactome capture (ptRIC)

The need for efficient 'RBPomic' studies in plant tissues led us to develop a plant-optimised RIC protocol that allows the study of the RNA-bound proteome in previously unamenable tissues such as plant leaves. In our latest publication we provide a detailed step-by-step protocol and a detailed data analysis pipeline (Bach-Pages et al. 2020, Biomolecules).

Using ptRIC we identified 717 RBPs in Arabidopsis leaves, 75% of which had annotations linked to RNA, confirming the robustness of the approach. Interestingly, the remaining 25% are novel RBPs and included metabolic enzymes and proteins from the photosynthetic apparatus that engage with RNA in plant leaves. Importantly, ptRIC allowed discovery of RBPs from different cellular compartments, including not only nucleus or cytoplasm, but also chloroplast and mitochondria.

Applications of ptRIC

ptRIC represents an excellent tool to identify and discover RBPs from leaves tissue, although we envisage it can also be applied as such or with small modifications, to other tissues such as roots. Of note, the use of ptRIC can be extended to agriculturally and economically important plant species beyond *A. thaliana* and can be instrumental at identifying novel RBPs and RNA-binding domains. Furthermore, ptRIC offers the unprecedented opportunity to study RBP dynamics in response to physiological, pathological and environmental cues.

Link to the paper:
https://www.mdpi.com/2218-273X/10/4/661

GARNish
Plant RNA Interactome Capture

Marcel talked about this paper on the GARNet Community Podcast:

http://blog.garnetcommunity.org.uk/marcel-bach-pages-describes-the-plant-rna-interactome-capture-method/

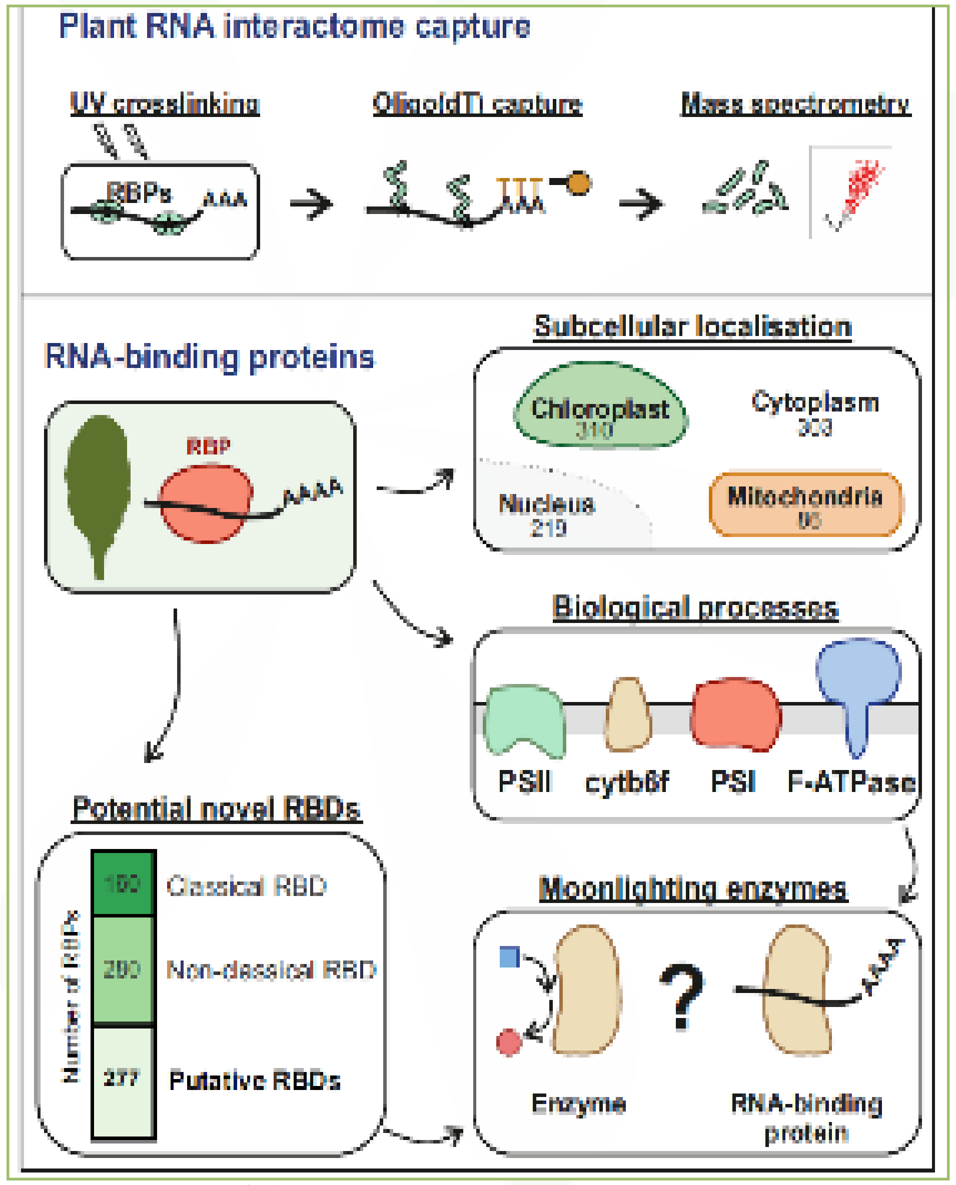

Figure 1: Schematic representation of plant RNA interactome capture (ptRIC). Using ptRIC the RNA-binding proteins (RBPs) bound to RNAs are identified, including RBPs from different subcellular compartments. These include RBPs involved in different biological processes and proteins not previously known to interact with RNA such as enzymes moonlighting as RBPs. ptRIC also allows discovery of potential novel RNA-binding domains

Introducing new projects funded through UKRI-BBSRC Responsive mode

Elucidating the role of ROS in mediating self-incompatibility induced PCD

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Maurice Bosch
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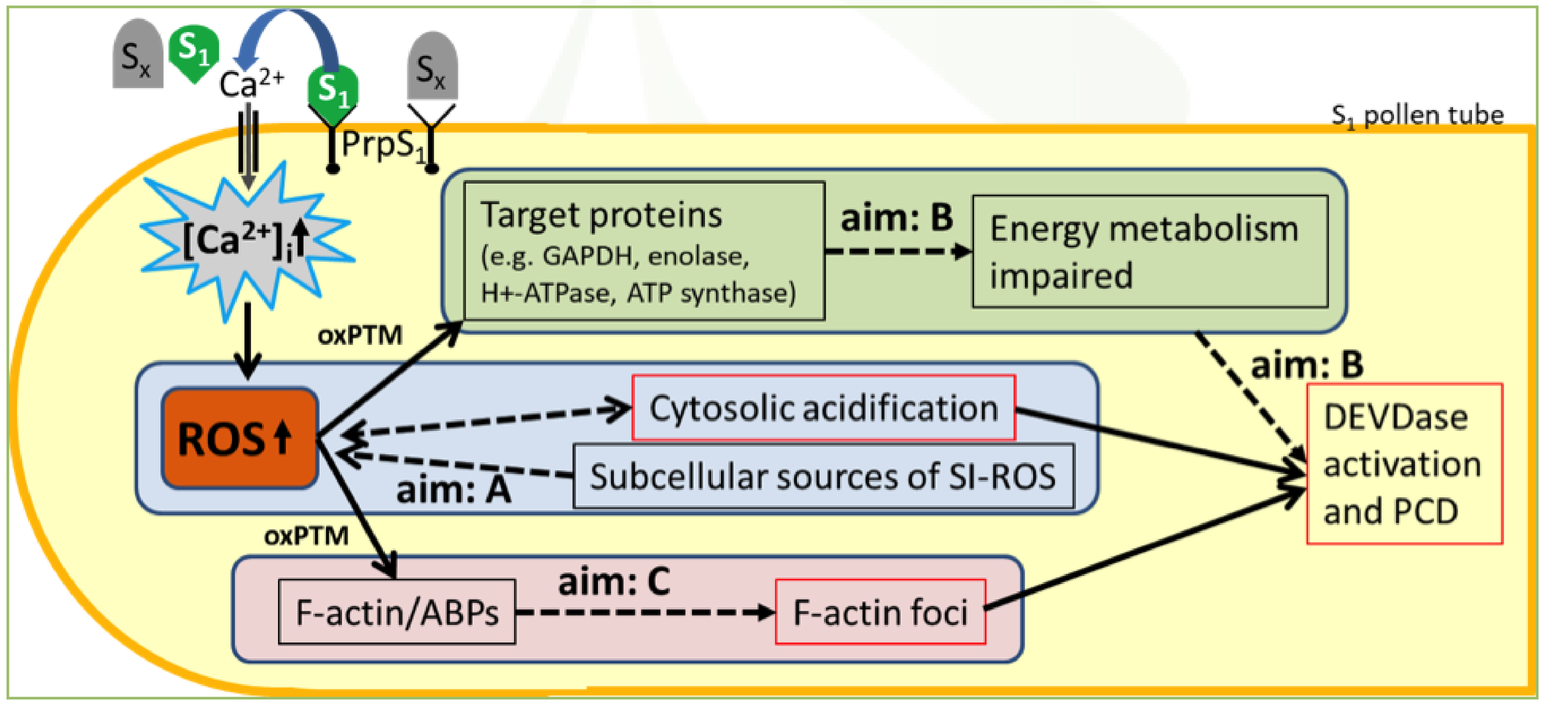
Aberystwyth University

Self-incompatibility (SI) is an important mechanism used by flowering plants to prevent self-fertilization. After pollination, SI utilizes cell-cell recognition to prevent self-fertilization by inhibition of pollen tube growth, which is crucial for the delivery of sperm cells to the egg cell inside the pistil. Mechanistically, one of the best-characterized self-incompatibility systems is that of Papaver (field poppy).

SI in Papaver is controlled and specified by S-determinants expressed specifically in the stigma (PrsS) and pollen (PrpS), respectively. Allele-specific interaction between these two determinants activates a network of intracellular signals in incompatible pollen that result in the rapid inhibition of pollen tube growth and, ultimately, programmed cell death (PCD). SI induces rapid increases in reactive oxygen species (ROS) that play a central role in the self-incompatibility response. These increases in ROS are involved in mediating the formation of punctate actin foci, a key and important feature of the Papaver SI response, and activation of a caspase-like activity (DEVDase) associated with PCD of incompatible vand predominantly irreversible oxidative modifications of pollen proteins (Haque *et al* . (2020) Plant Physiol DOI:10.1104/pp.20.00066).



Smirnoff and Bosch: Key components involved in SI-PCD and targets oxidatively modified by SI-induced ROS are shown within a pollen tube. The diagram illustrates known processes (solid black arrows) and unresolved events/hypotheses (pecked arrows) to be addressed in the project. OxPTM: oxidative posttranslational modifications.

Strikingly, cytoskeletal proteins and enzymes involved in energy metabolism are a prominent target for irreversible oxidation by SI induced ROS, suggesting that this is an important mechanism regulating SI in Papaver.

In this BBSRC funded collaborative project, we will combine biochemical, live-cell imaging and genetic approaches to determine how elevated ROS are mechanistically involved in the SI-induced PCD signalling cascade. We will set out to identify the subcellular source(s) of SI-induced ROS and linking the sites of ROS production to protein oxidation. We will test the hypothesis that SI-induced ROS impacts energy metabolism and determine implications for PCD. Likewise, we will determine how ROS-induced irreversible oxidative modifications of actin and actin binding proteins (ABPs) affect actin dynamics and organization.

The project benefits from the functional transfer of Papaver SI to Arabidopsis. The availability of engineered Arabidopsis "SI" lines, which provide a powerful and robust system to analyse Papaver SI using genetic approaches previously not feasible (Wang *et al* . (2020) J Exp Bot 71: 2451), will facilitate dissecting the role of ROS/oxidation in protein function/activity and SI-induced PCD.

Ultimately, the outcomes from this project will not only provide important mechanistic insights into the role of ROS in SI-PCD but also more broadly for our understanding of the consequences of ROS induced protein damage in plant cells.

Engineering ion flux of the stomatal complex for enhanced photosynthesis and water use efficiency

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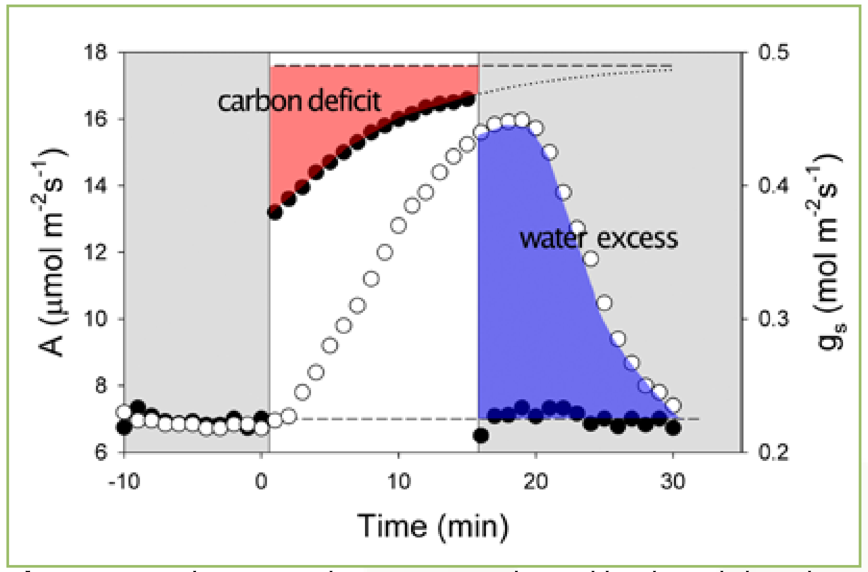
Universityof Glasgow

Co-Is: John Christie
University of Glasgow

Wendy Harwood
John Innes Centre

Stomata are pores that open and close to protect against leaf drying while enabling CO2 entry for photosynthesis. They provide the major route for gaseous exchange between the interior of the leaf and the atmosphere, affecting both photosynthesis and water loss via transpiration. Much effort over the past three decades has focused on ways to increase efficiencies associated with photosynthesis, including that of water. Water use efficiency, WUE (generally defined as the amount of carbon fixed per unit water lost via transpiration), provides a measure of photosynthetic output in the context of this basic resource and is important as an agriculturally-relevant marker.

One approach to improving WUE is to reduce stomatal density and has proven effective in reducing crop water demand, for example in Drysdale wheat. There is a cost, however, because reducing the conductance for transpiration this way inevitably also reduces the conductance across the leaf epidermal layer to feed the photosynthetic demand for CO2. This cost therefore comes as a reduction in net carbon assimilation.



Blatt: Here carbon assimilation (A) is indicated by the solid circles and stomatal conductance by the open circles. Gray background indicates low light and white background indicates high light.

Approaches that circumvent this carbon:water trade-off pose greater challenges but also hold much promise. In particular, since the studies of Pearcy and colleagues in the 1980's, it has been recognised that significant gains in WUE might be realised if the kinetics of stomatal movements were better matched to fluctuations in light and photosythetic demand. Most important, such gains also come without a cost in carbon fixation, at least in principle.

Consider a field on a sunny day as clouds pass overhead. Very substantial changes in photosynthetically-active radiation (PAR) will occur over periods of seconds to minutes with the change in cloud cover. Photosythesis will respond almost instantly to these changes in light, but stomata are generally much slower. This mis-match in kinetics can lead to periods during which stomata restrict photosynthesis as PAR rises as well as periods of transpirational water loss without concurrent carbon gains when PAR drops and stomata lag behind.

As a proof-of-principle, last year we published in SCIENCE the results of our studies to introduce a light-gated K+ channel, BLINK1, in the guard cells of Arabidopsis. Because K+ accumulation and loss by guard cells is a major driver for stomatal opening and closing, we reasoned that bringing this K+ flux directly under light control could accelerate stomatal movements and promote WUE. It did - and without a cost to carbon assimilation. Indeed, we found that accelerating stomatal movements enhanced carbon assimilation as well as WUE, precisely what was expected if both stomatal opening as well as closing were affected.

The challenge now is two-fold. First, we want to know if further gains are possible by manipulating not only guard cell transport but also ion transport of the surrounding epidermal cells. A long history of evidence suggests that the surrounding cells provide a reservoir of ions for stomatal movements and also help promote stomatal kinetics by alternately removing and adding 'back pressure' on the guard cells as they swell and shrink. There are some very fundamental questions here, too, because we know almost nothing about how ion transport in guard cells is coordinated with that of the surrounding epidermal cells. This will now be the focus of work in the Blatt and Christie laboratories at Glasgow.

Second, from a practical standpoint we want to know if the gains in assimilation and WUE that we achieved in Arabidopsis can be translated to crops, either with or without manipulations of transport in the surrounding epidermis. Translation to another crucifer, Brassica, and to the monocot barley will also help inform on the relative importance of the surrounding epidermal cells, as the mechanics of the stomatal complex in grasses is very different from that of dicotyledenous plants. This will be the focus of work in the Harwood laboratory at the John Innes Centre, Norwich.

Confirmed Key Note Speakers

- **Caroline Dean** (John Innes Centre, Norwich, UK)

- **Keiki Torii** (University of Texas, Austin, USA; Nagoya University, Japan)z

Confirmed Plenary Sessions:

- **Epigenetics and Chromatin Biology.**
- **From Models to Crops.**
- **The Dynamic Proteome**
- **Robustness in Genetic Networks**
- **Photobiology and Optogenetics.**
- **Principles of Morphogenesis.**

- 22 Community Concurrent Session with 44 hours of potential talks from submitted abstracts. £500 for each organiser to distribute. Deadline **July 31st 2021**

- Conference Venue: ICC Belfast, https://www.iccbelfast.com/
- Conference dinner at Titanic Museum

Spotlight on: University of Nottingham

Compiled by Malcolm Bennett and Jennifer Dewick

University of Nottingham: a diverse interdisciplinary research ecosystem

Plant-related research is performed across several different Departments and Divisions at the University of Nottingham. These include the Schools of Biosciences, the Computer Vision Laboratory in Computer Science, Life Sciences and Mathematics. The strongly interdisciplinary ethos of our science originates from the BBSRC/EPSRC Centre for Plant Integrative Biology (CPIB; 2007-2018), whose research remit has recently been superceded by the transdisciplinary Future Food Beacon of Excellence (2018-to date) which also integrates animal and food science, nutrition, engineering, social science and economics.

Within Biosciences, plant research is focused in >30 research groups and >200 research staff and students spanning the Division of Agriculture & Environmental Sciences and Division of Plant & Crop Sciences. These include internationally recognised Nottingham centres such as NASC and the Wheat Research Centre, in addition to world class experimental platforms such as the Hounsfield Facility which integrates Maths, Plant, Crop, Soil and Computer sciences.

Department/Division Twitter accounts:
@PlantSciNottm
@CVLNottingham
@UoNFutureFood
@NascArabidopsis
@UoNCMMB
@UoNBiosciences
@UoNMaths
@Notts_WRC
@UoNHounsfield

Future Food website:
www.nottingham.ac.uk/future-food
Future Food blog:
www.blogs.nottingham.ac.uk/futurefood

The Hounsfield Facility

Jonathan A Atkinson
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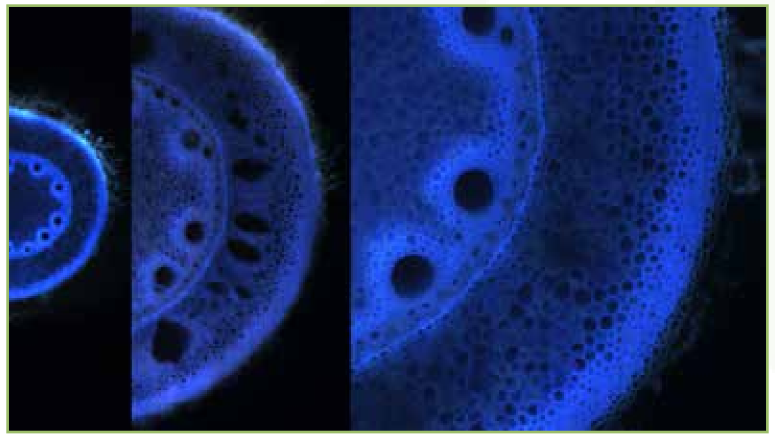
Senior Research Fellow and Technologist in Phenomics

My research interests are on the genetic control of root architecture, anatomy and physiology, primarily in crop species such as wheat. More recently, my research has focused on the complex interactions between roots and soil; in particular how pore structure effects and facilitates root growth.

Alongside research, through my role as the Phenomics Technologist within the Future Food Beacon, I design, develop and build novel phenotyping technologies, facilitating research from the cellular to whole plant and field scale.

I also manage the Future Food MakerSpace (a dedicated resource for developing innovative and integrated phenomics solutions) and co-manage the new Laser Ablation Tomography facility (for high throughput phenotyping of plant anatomy).



Atkinson: Laser ablation tomograph of a pearl millet adventitious root. Left to right: 2x, 5x, 10x magnification.

Leah Band
Leah.band@nottingham.ac.uk

Trained as a mathematician, my research focusses on creating models to gain understanding of plant growth and development. I am particularly interested in developing multilscale models to understand how processes at smaller spatial scales combine to produce organ-scale phenotypes.

Much of my research focusses on cell-based models to understand how cellular processes affect organ patterning; for example, understanding how the localization and properties of membrane transporters or metabolism enzymes affect hormone distributions. These models have provided insights into how auxin redistributes during a gravitropic response, how flux through plasmodesmata affect auxin patterns in the root tip, how auxin dynamics underpin lateral root initiation, how dilution of GA leads to growth patterns and how water fluxes through aquaporins affect lateral root emergence.

These projects have also led to my interest in how we can best use different types of experimental data to parameterise and test models to improve our understanding. In current projects, I am also working with functional-structural models to characterise how properties of the individual roots affect the resulting shoot biomass, studying the networks underpinning cell-cycle regulation and investigating how the environment affects hormone dynamics and hence phenotypes.

Malcolm Bennett
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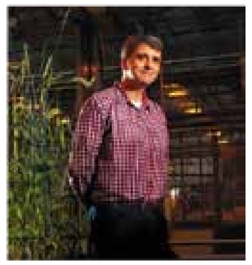
Head of Plant & Crop Sciences



The hidden half of plant biology has been an enduring interest throughout Malcolm's 20 year research career at Nottingham. His team has characterised many of the regulatory signals, genes and mechanisms that control root growth, development and adaptations to their soil environment. Highlights include identifying the first transport protein described in plants for the hormone auxin termed AUX1 which controls root angle (Bennett *et al* , 1996, Science); and elucidating how roots preferentially grow towards or branch towards water availability using hydrotropism (Dietrich *et al* , 2017, Nature Plants) and hydropatterning responses (Orosa-Puente *et al* , 2018, Science; von Wagenheim *et al* , 2020. Nature Plants).

Over the past decade, Malcolm has embraced a systems biology approach to study root development, helping establish the BBSRC/ EPSRC Centre for Plant Integrative Biology (CPIB) at Nottingham. Highlights include elucidating how hormones like auxin control root growth and branching (Band *et al* , 2012, PNAS; Swarup *et al* , 2008, Nature Cell Biology). His team is currently translating knowledge about the genes and signals regulating key root traits such as angle, depth and branching to re-engineer root architecture in crops and improve sustainability and yields (Huang *et al* , 2018, Nature Comms; Giri *et al* , 2018, Nature Comms; Bhosale *et al* , 2018, Nature Comms).

To uncover new traits determining water and nutrient use efficiency in crops, Malcolm and colleagues in Biosciences, Maths, Engineering and Computer Sciences have pioneered efforts to non-invasively image roots in soil. They have created the Hounsfield Facility (https://www.nottingham.ac.uk/microct/), an unique X-ray based root imaging platform integrating robotics, microCT scanners and analysis software. Research highlights include imaging novel root adaptive responses in soil termed Xerobranching and Hydropatterning, where roots only branch when in contact with water (Orman *et al* , 2018, Current Biology; Bao *et al* , 2014, PNAS).

Rahul Bhosale
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BBSRC Discovery Fellow
Nottingham Research Fellow
in Crop Functional Genomics
(Future Food Beacon)

My research is primarily focused on dissecting molecular mechanisms underlying root anatomical traits termed root cortical aerenchyma formation in maize and rice and root cortical senescence in barley and wheat. These traits enable greater acquisition of soil resources for less metabolic investment and thus improves yield under drought and suboptimal nutrient conditions.

Towards this, I am using functional genomics (e.g. Laser Capture Microdissection, Single-Cell RNAsequencing and CRISPR-Cas9 gene editing) and high throughput phenotyping (Laser Ablation Tomography based Anatomics) approaches and work closely with researchers from Nottingham (Prof. Malcolm Bennett) and USA (Prof. Jonathan Lynch and Prof. Shawn Kaeppler). I also aim to use molecular assisted breeding approaches to translate generated knowledge into other under invested crops such as pearl millet.

I also lead a young team of 2 PhD and a MRes student working on diverse research topics including (i) characterising root traits conferring heat stress tolerance in rice (Aneesh Lale, PhD student supported by FFB Funded project "PaleoRAS - Palaeobenchmarking Resilient Agricultural Systems"), (ii) exploiting genetic diversity of seed structure, composition and functionality of pearl millet germplasm (Brighton Gapare, PhD Student supported by FFB Joint Nottingham-Rothamsted studentship) and (iii) Understanding hormonal crosstalk regulating root cortical traits (Samuel Wadey, MRes Student, FFB funded).

Additionally, we are actively involved in several national and international collaborative projects to (i) determine spatiotemporal gene regulatory networks underlying root adaptive traits such gravitropism, hydrotropism, hydropatterning, etc. and (ii) exploit genetic diversity of underutilised crops such as pearl millet, moth bean and foxtail millet to study root traits towards improving crop performance under abiotic stresses.

Anthony Bishopp
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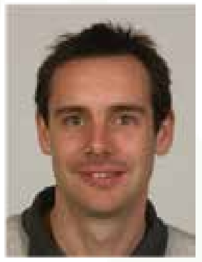
Royal Society University Research Fellow



My research centres on how two hormones, auxin and cytokinin, coordinate root anatomical patterning. We use the model plant, Arabidopsis thaliana, to uncover new regulatory components or interactions that enable specificity in auxin and cytokinin response. My primary focus is in the regulation of root vascular pattern, although the pleotropic nature of these hormones often encourages us to look at other processes.

Over 100 years ago, the Scottish botanist Claude Wardlaw, observed that plants with larger vascular cylinders produce more xylem poles. Using a combination of experimental and systems approaches, we have shown that the diarch vascular pattern seen in Arabidopsis can be altered, simply by changing the size of the vascular cylinder. This has led us investigate whether similar regulatory networks can specify vascular pattern in species with quite different anatomies. To this end we are using rice as a model system for plants with a larger vascular cylinder, and more recently also duckweeds as they have highly reduced roots systems. Our duckweed research allows us to investigate evolutionary loss of root complexity as they provide a natural trajectory from rooted to rootless species.

Martin Broadley
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Martin Broadley's research seeks to increase our understanding of mineral nutrient dynamics in food systems. A particular focus is on improving the nutritional quality of soils and crops, to support the need for more nutritious human and livestock diets. It also includes the development of long-term research and training partnerships with higher education and government research institutes in sub-Saharan Africa (SSA) and South Asia. Recent research highlights include identifying and characterising spatial controls of micronutrient deficiencies in Ethiopia, Malawi, Pakistan and Zimbabwe.

Long-standing experience of multi-disciplinary and multi-sectoral work, including with National Agricultural Research Systems, international research institutes, and the Food and Agriculture Organization of the United Nations

(FAO). In addition to an academic position at the University of Nottingham, UK, Martin is a part-time Senior Research Fellow (Agriculture & Food Systems), in the Research & Evidence Division of the UK's Department for International Development (DFID).

Alexandra Burgess

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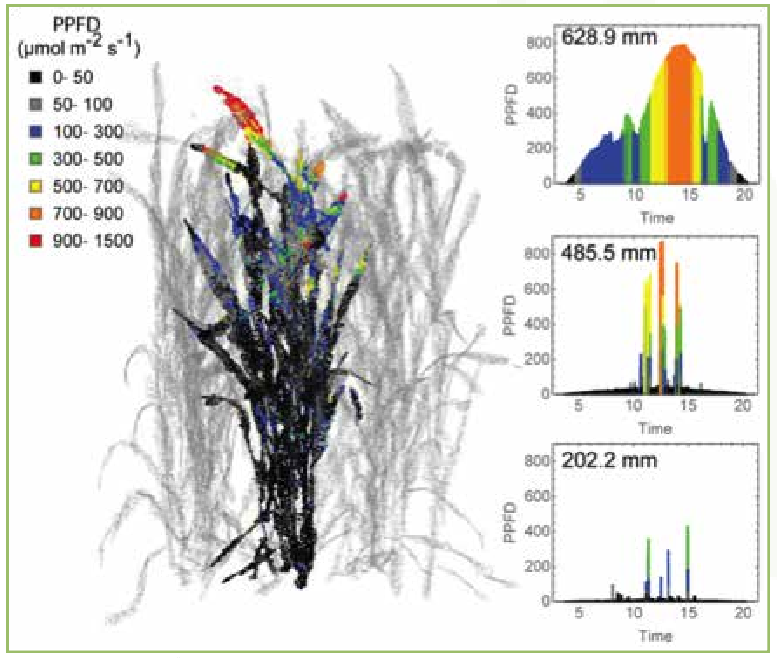
Alex is a newly appointed Leverhulme Early Career Research Fellow with strong ties with the Murchie lab, the Computer Vision Lab and Dr Matthew Robson from the University of Helsinki who specialises in canopy spectral ecology and ecophysiology. Her research explores how shoot canopy architecture determines light quantity and quality reaching leaf material and the corresponding response of photosynthesis. She uses methods such as 3-dimensional reconstruction, ray tracing, deep learning, chlorophyll fluorescence, gas exchange and empirical mathematical modelling to phenotype plants and assess whole canopy productivity.



Burgess: Visualising root exudates

Alex looks at multiple crops and has an interest in alternative cropping practices including intercropping and agroforestry.

Alex was previously based at Queen Mary University of London under Professor Alexander Ruban where she used biochemical and biophysical approaches to investigate how molecular components of a leaf determine how light is absorbed and used. She was also involved in a European consortium to help identify and prioritise opportunities for increasing future yield production in Europe.

Gabriel Castrillo

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Nottingham Research Fellow in Plant Microbiome (Future Food Beacon)

Gabriel Castrillo is a Nottingham Research Fellow in Plant Microbiome, and a member of the Future Food Beacon of Excellence. Gabriel's research is focused on understanding how plants and microbes interact, in the context of nutrition. He examines how microbes help plants cope with nutritional deficiencies, and how the plant impacts the structure of the microbiome of the root, and the leaf. Gabriel joins UoN from the University of North Carolina, Chapel Hill. He published his first Nature paper in 2017.

His work is mainly focused on the study of how plants and microbes interact. He is interested in doing that in the context of nutrition. He wants to understand how microbes help the plant to cope with nutritional deficiencies and to understand how the plant controls the structure and function of its microbiome.

I did my PhD working in phosphate starvation, in Spain. When I finished, I realised that phosphate was intimately related with arsenate, so I started working with arsenate signaling in plants in my first postdoc. After I finished that, I realised there was another layer that I was not considering, the contribution of microbes. I moved to the USA to complete this research at The University of North Carolina at Chapel Hill. I went from phosphate starvation in sterile conditions, to arsenate, and then I started researching the interaction of microbes and plants in the context of phosphate starvation. I become more and more interested in studying the entire plant ionome, all elements at the same time. I knew David Salt was working on this at the University of Nottingham, and I found this NRF position at the same time. Now I have the possibility to cover how the microbes not only affect phosphate or arsenate, but all the elements at the same time. I find this idea really fascinating, which I why I decided to join the team here.

Etienne Farcot

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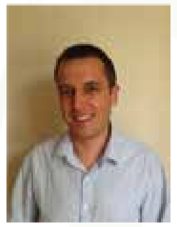
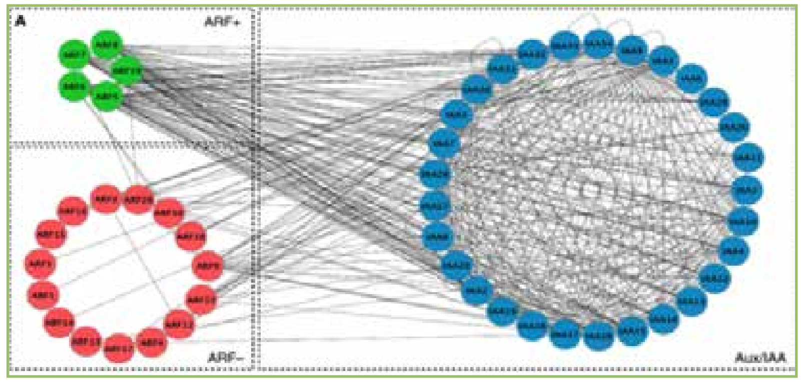


Applied mathematician interested in dynamical systems of a discrete and/or continuous nature. I have a long-standing interest in the modelling of gene networks, their dynamics and their relation with processes taking place at macroscopic scales. This includes work on the auxin signalling pathway, spatio-temporal patterns induced by auxin transport, in particular in the context of meristem growth, and phyllotaxis. I enjoy collaborating with scientists with varied backgrounds and see how often mathematical modelling can provide surprising insight into complex biological processes.



Farcot: Modelling gene networks

Sina Fischer

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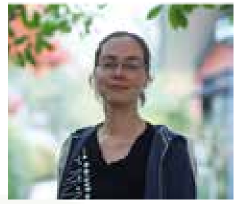
Nottingham Research Fellow in Functional Genomics (Future Food Beacon



Sina Fischer is a Nottingham Research Fellow in Functional Genomics, and a member of the Future Food Beacon. Sina researches Whole Genome Duplication in *Arabidopsis thaliana*. Her research seeks to understand the genetics behind traits that appear when the whole genome is duplicated. Sina intends to expand her research into rice and barley while an NRF. Before joining the University of Nottingham, Sina was a Research Fellow at the University of Aberdeen, and completed her PhD at the University of Bayreuth in Germany

I am researching Whole Genome Duplication in *Arabidopsis thaliana*. I used to work in Germany at the University of Bayreuth where I studied natural variation in heavy metal tolerance which means I was working with cadmium and manganese, lead, zinc. I was focused on the ionome of the plant and on natural variation. When I was finishing my PhD I was looking into where I could go to next, and whom would be the best person to learn from. David Salt is THE expert on the plant ionome. He defined the term. It describes all the ions that are present in the plant at any given time point. I approached him and together we designed a project that was based on a paper he published in 2013. I was first based at the University of Aberdeen, and then I joined him here in Nottingham.

Rupert Fray

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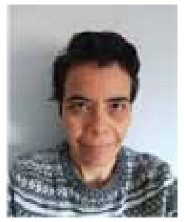
Deputy-Head of Plant & Crop Sciences

Eukaryote messenger RNA is processed by the addition of a cap, a poly(A) tail, removal of introns and the modification of certain nucleotides. The most common internal nucleotide modification converts adenosine to N6-methyladenosine (m6A). The formation of m6A occurs co-transcriptionally and we are interested in understanding how this methylation event is directed, and characterising the enzyme complex responsible. We are also studying the consequences of this methylation for RNA fait and the role of RNA binding proteins that recognise m6A containing transcripts.

Using Arabidopsis as a model system, we were able to show that the modification is essential for development and we were able to identify several of the components of the large enzyme "writer" complex. This m6A writer complex proved to be well conserved between plants and metazoans and the human equivalents are receiving much attention due to their common mis-regulation in cancer. Plants engineered to have reduced levels of m6A show reduced auxin responsiveness, altered floral development and increased susceptibility to salt stress. Working with the Gregory group in Pennsylvania, salt responsive mRNAs were shown to stabilised by the presence of m6A.

Although we work primarily with Arabidopsis, we have also worked on various other eukaryotes, such as yeast (S. cerevisiae), where m6A is required for regulating responses to nutrient stress that lead to meiosis and sporulation. In collaboration with the Soller lab in Birmingham, we showed that m6A has a role in sex determination in Drosophila through regulating the alternative splicing of the Sexlethal transcript. We have ongoing collaborations looking at the role of m6A as well as cap adjacent modifications (not found in plants) in neuronal plasticity required for learning and also their involvement in prostate, breast and brain tumours. Our ongoing work in Arabidopsis is focused on how m6A methylation marks effect the translatability of mRNAs and how this can vary under different conditions and environmental signals

Zinnia H Gonzalez-Carranza



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In my group we study the sustainable, holistic and ethical use of Mezquite (Prosopis sp) to improve the wellbeing of marginalised communities in the drylands of low- and middle-income countries. We are using community participatory and citizen approaches, and in collaboration with scientists from the UK, Mexico, Kenya and Tanzania, and other stakeholders.

We are studying the nutritional, anti-nutritional, anti-carcinogenic and toxicological properties of Mezquite. We are also generating prototypes of water filtration systems with mezquite products to provide alternatives for safe water for dryland communities. Our research is responding to community needs that they had shared with us. Additionally, we are generating training opportunities for the communities to teach

Gonzalez-Carranza: The Mesquite Project

them how to use and benefit from mezquite in a sustainable, holistic and ethical manner. Funds from our research come from GCRF, the British Council, the Science and Technology Council of Durango, Mexico, The Mexican National Forest Commission, and the government of Sinaloa. We are engaging with the governments of Mexico, Kenya and Tanzania to influence policy and our transdisciplinary project has received attention on television, radio and press in our partner countries.

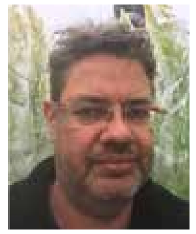
We are also elucidating the molecular mechanism of the Arabidopsis HAWAIIAN SKIRT (HWS) gene and its rice and maize orthologues in plant development and responses to stress. We established the importance of HWS in microRNA biogenesis, and we are translating this knowledge. We aim to produce more robust and tolerant crops to environmental changes.

https://www.mezquiteproject.org

https://www.nottingham.ac.uk/biosciences/people/zinnia.gonzalez-carranza

Facebook: @MezquiteProject
Twitter: @GCRF_Mezquite

Neil Graham



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Worldwide, millions of people have diets deficient in many elements (e.g. Fe, Ca, Zn, Se), causing a range of health and developmental problems. With populations increasing, there is a requirement to increase agricultural efficiency to produce more nutritious food. My group focuses on plant mineral nutrition, with the goal of crop improvement. This involves studying the acquisition from soil, transport and storage in different organs. We are improving nutrient uptake and translocation to improve crop fertiliser use efficiency. This will reduce the use of fertilisers, which are a major expense for farmers, produced from limited resources and can cause pollution of water sources. We are also manipulating mineral nutrition to increase the nutritional content of food. This can be improved by conventional breeding using molecular markers, genetic modification or though the use of specialised fertilisers. To achieve these goals, we collaborate with research groups in Universities, research institutes and industry in the UK, France and Africa.

My group uses a range of techniques including molecular biology, physiology, high-throughput elemental analysis, glasshouse and field studies. To understand the genetic control of plant nutrition, we are using associative transcriptomics and GWAS in *Brassica napus* and pearl millet. Pearl millet is an underutilised crop grown in sub-Saharan Africa that is drought tolerant and contains high levels of nutrients.

In *B napus* we identified a range of genes responsible for Ca and Mg including a range of transporters, flowering genes and nuclear transport factor. For P utilisation we identified several root

Graham: Analysing Brassica germplasm

hair genes and are currently investigating the relationship between root architecture, anatomy to P utilisation using sectioning and imaging techniques.

To further our work on *B napus* we are part of the Oilseed rape genetic improvement network (Oregin) funded by DEFRA, which provides open access field trials, genetic information and resources to the community. We are also investigating the biofortification of onions and potatoes with Se and looking at the effect of Se enriched extracts on diseases using cell-based assays. Increasing the mineral content does not mean that this is available in the diet due the presence of antinutrients e.g. phytate. We are investigating the genetic and environmental control of phytate levels in wheat. This is a major antinutrient that sequesters positively charged (e.g. Zn) ions making them unavailable. The goal is to produce lines with reduced phytate levels and hence increased nutrient availability.

Mike Holdsworth

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My research work in recent years has focused on understand the importance of oxygen sensing in plants, in particular discovering the roles that the N-degron pathways of ubiquitin-mediated proteolysis play in regulating plant growth and development, and response to the environment. This included the discovery that the branch of the pathway controlled by the E3 ligase PRT6 regulates ABA sensitivity of seed germination (PNAS 2009), acts as the molecular mechanism for oxygen sensing (Nature 2011) and nitric oxide sensing in flowering plants (Molecular Cell, 2014, Nature Comms 2019).

We showed that oxygen sensing through this pathway controls skotomorphogenesis (Current Biology 2015), is a general regulator of plant abiotic (Current Biology 2017) and biotic (BMC Plant Biology 2016, New Phytologist 2019) stress responses, manipulation of the pathway leads to waterlogging tolerant barley (Plant Biotechnology Journal 2016) and the pathway controls the stability of multiple proteins (Nature Comms 2018, New Phytologist 2020).

John King

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John is an applied mathematician with interests in the application of multiscale modelling techniques in systems and synthetic biology.

He has longstanding involvement in plant-science applications, initially as Modelling Director of the Centre for Plant Integrative Biology; his collaborations have included those on gene regulation, hormone transport and biomechanics

in root growth, plant fertility and seed development, with applications to both model and crop species.

Sean Mayes

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World agriculture today is focused on three cereals crops and one legume. Between them, rice, maize, wheat and soybean account for 75% of the plant-based calories consumed by the world population. While these will continue to play a significant role in feeding future generations, it is risky to rely on so few crops. As agriculture is forced to adapt to changing climates, decreased resources and increasing demand, there is an opportunity to diversify and localise crop use, particularly where those crops have retained special characteristics, such as drought tolerance.

Our lab in collaborations worldwide, is focused on tackling some of the constraints these crops face to being able to make a greater contribution to future agriculture, whether that it from the genetics and breeding, all the way through to a lack of market demand and products. We have just completed pseudochromosome level genomes for Bambara groundnut (*V. subterranea*) and Winged bean (*Psophocarpus tetragonolobus*) and beginning work on Moth bean (Vigna aconitifolia), while generating x10 coverage on 300 lines of Foxtail millet (*Setaria italica*). We also work extensively with colleagues on our Malaysian campus

Guillermina Mendiondo

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Guillermina Mendiondo is an Assistant Professor and Future Food Beacon of Excellence Research Fellow at The University of Nottingham. Guillermina works between the field and the lab understanding how crops sense environmental cues. Guillermina is an applied plant biologist with a background in molecular and crop physiology, with expertise in a variety of approaches that include plant physiology, molecular biology, biochemistry, cell biology, genetics and bioinformatics, in both genetic model systems and crops.

Her research has focused on understanding the molecular and genetic components regulating plant-environment interactions, particularly to define the biochemistry of how plants sense environmental change, and to identify promising targets that can be manipulated in agriculturally important crops. Her work has involved ongoing support and interactions with industry.

Guillermina's research investigates the impact of environmental stress on plant development and to date, her work has focused on the role of the N-degron pathways of targeted proteolysis as a central hub integrating responses to abiotic stresses in cereals. This included the discovery that the PRT6 branch of the N-degron pathway is conserved in barley (Hordeum vulgare) and preliminary data shows it can be manipulated to enhance stress resilience in crops. In addition, her lab is working to understand the regulation of seed dormancy and germination, as plant hormone signalling has proven to be a very successful target for improving grain yields and quality in cereals.

The ongoing goal of Guillermina's lab is to provide plant breeders with plant genetic resources capable of enhancing tolerance to environmental stresses, providing real-world impact, alongside understanding the fundamental mechanisms of plant abiotic stress. While the majority of this research has been carried out in Barley, this translational work now extends into wheat and B. rapa, with projects in the UK, South Africa, Zimbabwe, Indonesia, USA, Brazil and Argentina.

Hassan Moeiniyan Bagheri

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“Pick, Store, Buy: Shelf life extension and reduced waste for tomato production in Nigeria" Waste of highly nutritious fresh produce is a significant problem for developing countries, where 70% of the population can be engaged with the sector. It threatens the growth of primary agriculture industries, the livelihoods of workers, economic progress and food security. Whilst Nigeria is the largest producer of tomatoes in west Africa, 50% of harvested produce perishes, before it can be distributed and sold to consumers. This project will develop an integrated, cost effective and sustainable solution to manage the postharvest value chain where most produce is lost. The project partners, one based in Nigeria, one in South Africa and two UK organisations will deploy cutting edge technology from biological sciences, physical and sensor engineering to develop Pick, Store, Buy will focus on three key innovations for the Nigerian tomato sector 1. ripening suspension using air purification and the removal of ethylene a key ripening hormone which is produced by plant tissues, 2. printable robust and portable microelectronics to measure real time key environmental factors that control ripening 3. shelf life prediction using gene discovery and real time data streaming algorithms. An extensive project partner communication programme in Nigeria will be critical to raising awareness and implementation of this much needed technology in the fresh produce value chain

Sacha Mooney

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Professor Sacha Mooney holds the Chair in Soil Physics at the University of Nottingham and Director of the Hounsfield Facility. He is also the current President of the British Society of Soil Science. Sacha is a soil physicist whose primary interests are focused on the key role soil structure plays in controlling and regulating soil function.

His early work was concerned with understanding soil-water interactions but more recently he has developed an interest in rhizosphere processes and in particular understanding how the soil physical environment in impacted upon and conversely regulates root-soil-microbe interactions. His particular expertise is focused on the use of imagery to quantify the soil pore network and root systems architecture across a range of spatial scales and he has recent and current BBSRC, Newton Fund and GCRF grants focused on imagery of soil and plant systems concerned with alleviation of compaction by cover crops, the genotypic role of wheat in modulating the biophysical rhizosphere, the legacy impact of legumes in Sub-Sahran African soils and impact of zero tillage on carbon sequestration and greenhouse gases emissions.

Soil structure is a vitally important soil property. It provides the network through which all soil transport and storage processes and mechanisms take place. The precise arrangement of pore space in terms of the size, shape and connection of individual pores regulates the storage of water, transport of solutes and diffusion of gases. It is subject to regular perturbation via our climate and the way in which we choose to manage soils. In our laboratory we use X-ray Computed Tomography to visualise and quantify this arrangement of the microstructure of soil in order to better under how the plant-soil systems operates. In a recent Newton Fund project (NUCLEUS, A Joint a virtual joint centre to deliver enhanced Nitrogen Use effiCiency via an integrated SoiL-plant systEms approach for the Uk & BraSil; BB/N013204/1) we explored the role of forage grasses (used as part of an integrated crop-liverstock system) in improving nitrogen use efficiency in Brazil. We showed that the grass most commonly used (Brachiaria ruziziensis) was sub-optimal and that varieties with a finer root system (e.g. Brachiaria brizantha) had enhanced nitrogen use efficiency driven by increase in the pore complexity in the rhizosphere which enhanced the residency of nitrate.

GARNish
Spotlight on University of Nottingham

Erik Murchie

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Crop productivity is reliant on the efficient operation of primary processes such as photosynthesis and water loss and these key events within the plant are highly sensitive to climate change. We can identify targets for improvement in terms of existing genetic variation and genes underlying key processes.

I am Professor in Applied Plant Physiology at the University of Nottingham and my lab analyses photosynthesis, water loss and abiotic stress at the leaf, whole plant and canopy level. We use techniques of gas exchange, chlorophyll fluorescence, 3D canopy reconstruction, remote sensing on diverse crop wheat and rice germplasm and work with international partners to identify key variation in primary traits that can improve resource use efficiency. We are interested in spatiotemporally integrated physiology, for example this may include how little studied nocturnal processes operate to influence yield or how photosynthesis responds to rapidly fluctuating light.

Canopies are complex structures which cast variable light patterns in time and space as a result of 3D structure and movement. We are evaluating how such properties influence photosynthetic productivity: the 4-dimensional plant. Another important process is photoprotection, a suite of plant processes that help to prevent photosynthesis losses at high light but which has been clearly shown to influence whole plant productivity and yield in the variable light of a crop canopy. We use the concept of canopy radiation use efficiency to integrate these component processes and determine crop productivity.

Markus Owen

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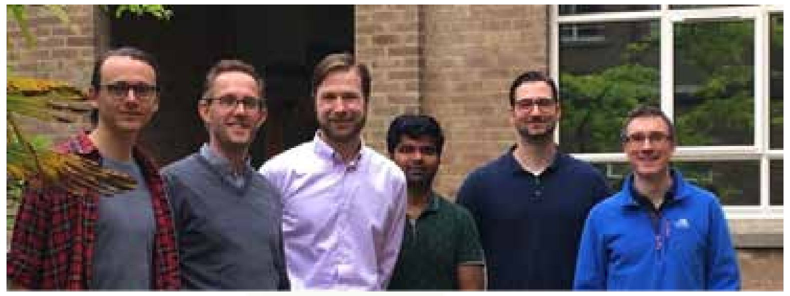
I am Professor of Mathematical Biology in the School of Mathematical Sciences at the University of Nottingham. Many years ago (1994!) I started my PhD in the mathematical modelling of immune cell interactions in cancer, and branched out into developmental pattern formation (but not yet in plants). A postdoc position in the USA combined lung mechanics with ecological invasions (some plants there - lupins), and after joining the University of Nottingham in 2004 I soon found myself involved with Malcolm Bennett and the great CPIB team of experimentalists, engineers, computer scientists, etc, modelling plant hormone transport and signalling.

We use a range of dynamical mathematical modelling approaches, including differential



Owen: OpenSimRoot team (L-R: Ernst Schäfer (UoN), Johannes Postma (FZJ), Chris Black (PSU), Ishan Ajmera (UoN), Christian Kuppe (FZJ), Markus Owen (UoN)).

equation models, parameter inference and computer simulation, in order to understand and predict the spatiotemporal nature of plant hormone signals (so far focusing on auxin and gibberellin), the pathways by which those signals are sensed and transduced, and the larger scale growth of root systems.

For the latter, a number of us at Nottingham contribute to the development of the open source software OpenSimRoot – a Functional Structural Plant Model that allows simulation of root system growth, nutrient and water uptake and environmental effects such as our recent work on modelling drought. In this we work with colleagues at Forschungzentrum Jülich and Penn State, and the photo shows some of the

Rumiana Ray

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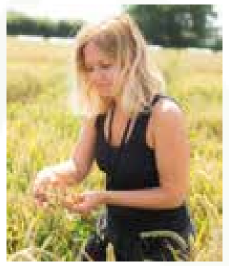

I am an Associate Professor in Plant Pathology at the University of Nottingham and my research is focussed on Crop Protection. My group works on soil-borne, stem-base and ear diseases that are caused by fungal pathogen complexes in cereals. We are interested in disease epidemiology, host- pathogen interactions and mechanisms of resistance to *Zymoseptoria tritici* and *Fusarium spp*. The etiology of the globally distributed soil-borne complex *Rhizoctonia solani* is also an important part of our research and we aim to develop integrative strategies for the control of Rhizoctonia diseases in oilseed rape. More recently, we have focussed on unravelling tripartite interactions, including host-mediated relationships between the English grain aphid and *Fusarium graminearum*, with focus on the resulting consequences for the fitness of the host, pest and pathogen. Further area of research includes the development of in field phenotyping and prediction tools for disease using molecular, hyperspectral and/or fluorescence signatures.

Tim Robbins

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The main area of research in my group is gametophytic self-incompatibility with a ribonuclease-based mechanism. This is one of the most widely distributed genetic mechanisms that prevents self-fertilization in angiosperms. We have studied self-incompatibility in members of the Solanaceae (Petunia and Solanum) and Rosaceae (Prunus and Pyrus).

We use Petunia as a model system to study the molecular biology of self-pollen recognition. Our recent work in Solanum is more applied and we have an interest in using CRISPR to develop self-compatible diploid lines of potato to allow the development of inbred lines.

David Salt

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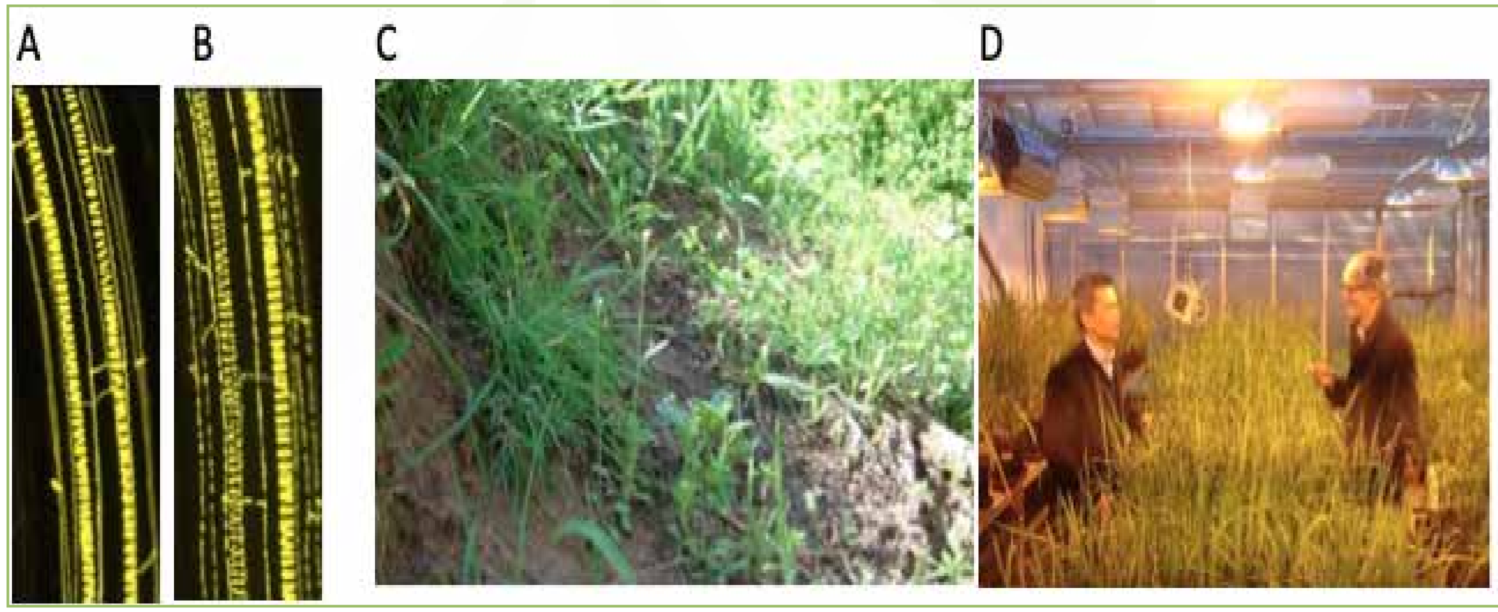
Functional and ecological genomics of mineral nutrient and trace element homeostasis

David E Salt's long term research interest is to understand the function of the genes and gene networks that regulate the mineral nutrient and trace element of plants (aka ionome), along with the evolutionary forces that shape this regulation. Salt has developed a novel functional genomics approach to study the ionome, combining high-throughput elemental analysis with bioinformatics, genetics and genomics in both laboratory and field-based studies.

Using this approach he has published papers describing work using both induced and natural variation in *Arabidopsis thaliana* that provide molecular mechanistic insights into the regulation of the plant ionome. This approach has identified genes involved in such processes as Casparian strip development, phloem function, sphingolipid metabolism, vesicular trafficking and disease resistance that impact the plant ionome. In depth analysis of Casparian strip development has identified several important molecular players, including the transcription factor MYB36 that controls Casparian strip development, and proteins involved in deposition of Casparian strip lignin (ESB1 & UCC1/2). Salt's research has also started to reveal the molecular basis of plant adaptation to the environment, including evidence that selection is acting on the Na-transporter HKT1 to adapt local populations of *A. thaliana* to coastal environments.

Salt has successfully used genome-wide association (GWA) mapping in *A. thaliana* to identify genes involved in regulating natural variation in the leaf ionome, including the accumulation of sodium, cadmium, arsenic and molybdenum. Translating this fundamental work into crops Salt has been working with rice to identify genes that control the mineral nutrient and trace element content of rice grain, including copper (HMA4), molybdenum (MOT1) and arsenic (HAC1).



Salt: Casparian strip in wild-type (A) and esb1 mutant (B). Coastally adapted Arabidopsis thaliana growing in North Eastern Spain (C). Close collaborator Prof Fangjie Zhao (Nanjing Agricultural University) with David Salt discussing joint projects on rice ionomics (D).

Further, to encourage a diverse group of researchers to participate in ionomics, Salt has developed a unique online web-based community portal called the ionomicsHUB (www.ionomicshub.org), now over 10-years old. The ionomicsHUB focuses on both workflow control for high-throughput data collection and also delivery of ionomic data to the community. More recently, Salt is the founding Director of the Future Food Beacon of Excellent, a multimillion pound investment enabling interdisciplinary research across the food system (www.nottingham.ac.uk/future-food) with stakeholders from HEI, business, civil society and government, both nationally and internationally.

Graham Seymour

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For many years my lab has been studying the biochemical and molecular basis of fruit ripening. The research has identified a spontaneous epigenetic mutation that governs the ripening process, we have been deeply involved in delivery of the tomato genome sequence and identified a gene controlling tomato fruit softening and shelf life. The influence of epigenetic factors in the control of ripening is a current focus and we generating and characterising a tomato epigenetic recombinant inbred line (EpiRIL) population as part of a collaboration with Philippe Gallusci at University of Bordeaux / INRA, Paul Fraser at Royal Holloway and Jim Giovannoni at Cornell University.

Tomato is one of the most consumed fruits and provides important vitamins and minerals in the human diet. Generating long shelf life tomatoes with excellent flavour and nutritional characteristics is an important commercial aim. At present natural non-ripening mutations are utilized in commercial practice to slow ripening,

Graham Seymour: http://blogs.nottingham.ac.uk/researchexchange/2018/12/10/long-live-the-tomato/

but these can have detrimental effects on the development of flavour development and other ripening events. Our recent discoveries published in Nature Biotechnology in 2016 offer potential to enhance tomato shelf life without the need to use non-ripening mutations as in current commercial practice.

I am now semi-retired, but still committed to seeing gene discoveries from the lab enter commercial practice. I also now have time to follow a long held interest to paint paleo-art reconstructions of ancient environments, an example of which my colleague Dr Susannah Lydon featured on her twitter page (https://twitter.com/susieoftraken/status/1167085646319632389).

Craig J Sturrock

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Dr Craig Sturrock is a Principal Research Fellow and Manager of the Hounsfield Facility, a dedicated X-ray imaging research facility for rhizosphere research.

Craig's primary research focus is on developing methodologies to enable quantification of the soil-plant-microbe ecosystem

GARNish
Spotlight on University of Nottingham

Sturrock: Using X-ray imaging to visualise roots in soil

ranging from micro-scale changes in soil structure to the quantification of the response of plant root system architecture to abiotic and abiotic stress. He recieved his PhD in microbial ecology from the University of Abertay Dundee in 2002.

Since joining University of Nottingham in 2010 he has worked on a diversity of projects is to apply knowledge and expertise in X-ray imaging and image analysis to characterise a wide range of heterogeneous materials. These techniques have been applied to collaborative projects with colleagues in materials science, engineering, veterinary medicine and food science leading to the publication of over 70 papers in the last 10 years.

Current projects include Principal Investigator at UoN on the EU2020 project TOMRES (grant id: 727929) which seeks to identify strategies and solutions to safeguard tomato yield to combined water and nutrient stress. The work at Nottingham is using X-ray imaging to identify novel root traits involved in combined stress resilience. He is also involved as Co-I on two GCRF projects in Sub-Saharan Africa. The CEPHaS project is a joint undertaking between colleagues in Zambia, Zimbabwe, Malawi and the UK to strengthen our shared capacity to study how conservation agriculture practices affect the behaviour of water in soil-crop-groundwater systems. LegumeSELECT (BBSRC: BB/R020590/1) is a multidisciplinary research project aimed at increasing the contribution of legumes to smallholder livelihoods in Sub-Saharan Africa (SSA) by enabling more appropriate legume selection decisions.

Debbie Sparkes

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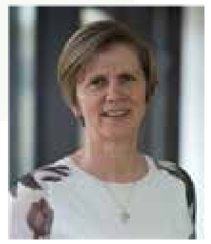
Head of Agriculture & Environmental Sciences Division)



My research aims to use an understanding of crop physiology to inform crop management systems and future crop improvement. For example, BBSRC funded research on lodging has enhanced understanding of the plant characteristics that lead to lodging in wheat and has enabled growers to reduce the risk of lodging by changing their crop management practices, thereby preventing yield loss and protecting crop quality.

The majority of my research is funded by industry, either directly or in collaboration with Innovate UK. Current research includes a number of projects on the physiology and agronomy of sugar beet. For example, there is great variation in canopy architecture of commercial sugar beet varieties, and we are investigating the impact of canopy architecture on radiation use efficiency and water use efficiency of the crop.

Sparkes: Out in the field with collaborators from the Processors and Growers Research Organisation

A Knowledge Transfer Partnership (KTP) with the British Beet Research Organisation aims to identify physiological traits of sugar beet that are related to pest and disease tolerance. These three projects will all inform variety selection by growers and also trait selection by breeders.

I work with Professor Neil Crout on a number of projects that link modelling with crop physiology including another KTP, this time with the Processors and Growers Research Organisation, which aims to improve the prediction of the yield and quality of vining peas.

I work on projects in the area of sustainable agriculture, most notably a long-term experiment at the University of Nottingham on Conservation Agriculture. In this work, I am collaborating with Professors Sacha Mooney and Sofie Sjogersten and together we are monitoring changes in crop growth, yield, soil properties and greenhouse gas emissions under different tillage regimes, with and without retention of crop residues. The experiment is now in its sixth year and we plan to continue this work to evaluate the long-term changes in soils and crop yield.

Dr Ranjan Swarup

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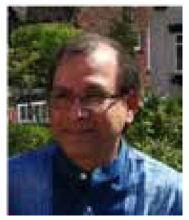

Global food security is one of the key issues facing world Agriculture. Food production needs to be increased in a sustainable manner under conditions of low fertiliser and water availability. One of the key areas of research in my lab is hormone regulated root development and its impact on above ground physiology.

I am currently leading a BBSRC-LINK grant investigating the role of phosphite-a plant biostimulant- in promoting plant development. Working with several industrial partners, my group has shown that foliar application of phosphite based formulations consistently enhances root growth and development in a range of crops (Rossall *et al* , 2016, Acta Horticulturae). This can have great implications for enhancing farm yield in a sustainable manner.

Another key area of research in my lab is auxins. Auxin is a key plant hormone regulating various aspects of plant growth and development. My work has focussed around AUX/LAX gene family that encodes high affinity auxin transporters which facilitate auxin transport. Recently, in collaboration with Malcolm Bennet group, we have shown that auxin influx carriers are required for low Phosphorus mediated root hair elongation response in Arabidopsis and rice (Bhosale *et al* 2018, Nature communications; Giri *et al* 2018, Nature Communications).

Currently my group is focusing on rice homolog of AXR4. Using genetic and functional complementation approaches, my group has shown that rice AXR4 is a functional homolog of Arabidopsis AXR4 (manuscript under preparation). As a proof of concept study in collaboration with Erik Murchie and Julie Gray (Sheffield University), we have manipulated stomata numbers in rice to reduce water loss and show that this results in improved tolerance to drought (Mohammed *et al* , 2018, Scientific Report).

GARNish
Spotlight on University of Nottingham

Ute Voß

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My group's research focuses on how auxin metabolism is regulated to guarantee optimal cellular auxin concentrations for plant growth and development.

Auxin is a key regulator of almost all aspects of plant growth and development. Depending on its local auxin concentration, a cell will develop into a specific cell type, thereby contributing to organ formation and growth. Auxin concentrations are established and maintained by a tightly regulated interplay between synthesis, degradation, transport, and perception. Even though breakthroughs have been made into how auxin synthesis, transport, perception, and response are regulated, we have little insight into how degradation contributes to controlling cellular auxin levels.

Auxin gradients are established and maintained by a tightly regulated interplay between homeostasis, signalling, and transport. Auxin can be inactivated by conjugation, but metabolic data suggest that auxin oxidation is the major auxin degradation pathway. We recently identified the two major auxin oxidising enzymes in the model plant Arabidopsis thaliana: DIOXYGENASE FOR AUXIN OXIDATION 1&2 (AtDAO1&2). Our research will answer how the interplay between different auxin degradation pathways fine-tunes cellular auxin concentrate and thereby contributes to plant development and acclimatisation to abiotic stresses. We currently focus our studies of DAO function on the model plant Arabidopsis thaliana. In parallel we are exploring explore the regulation and function of auxin degradation in other plant species including crops and basal land plants, to explore the evolution of this key regulatory mechanism.

Darren M Wells

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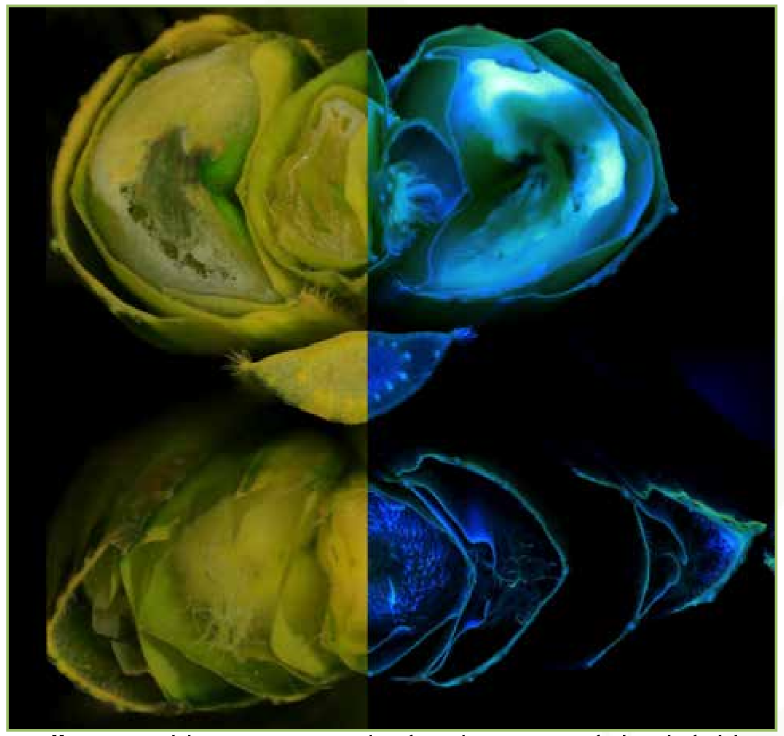
Principal Research Fellow in Plant and Crop Biophysics

Research in my group addresses fundamental and applied questions in plant biology using transdisciplinary approaches, in recent years focussing on integrated plant phenomics. I am a co-director of the Hounsfield Facility for Rhizosphere Research and a member of the Leadership Team for the Future Food Beacon of Excellence. We have recently established the UK's first Laser Ablation Tomography (LAT) facility for high-throughput phenotyping of plant anatomy at the Hounsfield and are currently complementing our root research with a canopy phenotyping facility. I also established and co-manage the Future Food-funded MakerSpace, a resource for developing innovative solutions to support research.

Research interests are multi-scale, ranging from subcellular (hormone fluxes underlying tropisms in Arabidopsis), organ-scale (root system architecture development in cereals) to whole plant responses (novel biostimulant activity of fungicides).

I am a member of the Operations Team of the H2020 project EMPHASIS-PREP, aiming to coordinate plant phenotyping infrastructures across Europe. Access to several of our current phenotyping platforms is available via the transnational access programme of the European Plant Phenotyping Network 2020 project (https://eppn2020.plant-phenotyping.eu)



Wells: Laser ablation tomograph of a wheat ear. Left: brightfield image. Right: laser illuminated image

Zoe Wilson

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The Wilson group works on the molecular genetic analysis of floral development and male reproduction, particularly pollen and anther formation. The overall aim of this is to improve crop yields by effective breeding strategies and optimising/controlling pollen fertility. We are particularly interested in the transcription factor regulatory networks in the anther tapetum. This maternal cell layer encases the developing pollen and serves to regulate the progression of late meiosis and pollen maturation, and as a factory for the production of pollen wall materials. We are using systems biology, bioinformatics and molecular approaches to construct and functionally test these regulatory networks through mutagenesis, high-resolution microscopy, luciferase assays, ChIP and protein interactions. Much of this analysis has been done in Arabidopsis, however these networks are conserved in crops, and we are also looking at the function and regulation of these pathways in Brassicas, rice, barley and wheat.

The projects in wheat and barley have particular focus towards understanding and controlling fertility with the aim of developing approaches for hybrid breeding. We are also very interested in the control of flowering and why it is switched off or extended when fruit set fails to occur and the different signals, including auxin and other hormones that are controlling this.

An area of particular importance is the impact of environmental stress on pollen development. Pollen development is particularly vulnerable to temperature stress, which can result in a lack of viable pollen with resultant losses in fertilization and thus significant reductions in crop yield. There is therefore a major challenge to maintain crop yields given increasing global temperatures and the increasing volatility and extremes in weather.

We are using GWAS to capitalise upon natural variation in rice to identify novel germplasm with increased tolerance to heat during reproduction. These targets are being analysed through CRISPR gene editing for their ability to confer enhanced resilience to environmental stress, with the aim of generating resilient breeding materials for future rice breeding.

John Foulkes

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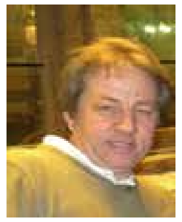

My research is focused on understanding physiological traits underlying genetic variation in grain number and yield potential and resource-use efficiency with a focus on nitrogen (N)-use efficiency in wheat. The research programme on grain number has quantified optimized patterns of stem and leaf distribution for enhanced ear growth in a diverse range of germplasm including synthetic-derived and landrace-derived genotypes in the different agro-climatic regions of the UK and Mexico (Rivera-Amado *et al* ., 2019) and has identified plant signalling mechanisms, including cytokinins, regulating allocation of assimilate to developing florets and grain number.

A major project is focussed on understanding the genetic regulation of these plant signalling traits through Genome Wide Association Study and identifying candidate genes for validation and marker development in wheat breeding in collaboration with CIMMYT, University of Florida and USDA as part of the International Wheat Yield Partnership (IWYP). Our research on the physiological and genetic basis of N-use efficiency focuses on understanding the mechanisms determining N requirements of wheat canopies according to structural, photosynthetic and reserve functions of N and understanding how N-use efficiency is related to canopy N-remobilization and senescence properties (Nehe *et al* ., 2020). We also have a strong interest in identifying novel diversity in wheat pre-breeding germplasm for NUE traits including root system architecture traits by developing high-throughput phenotyping techniques including thermal and hyperspectral imaging. t.

Computer Vision Lab (Computer Sciences)

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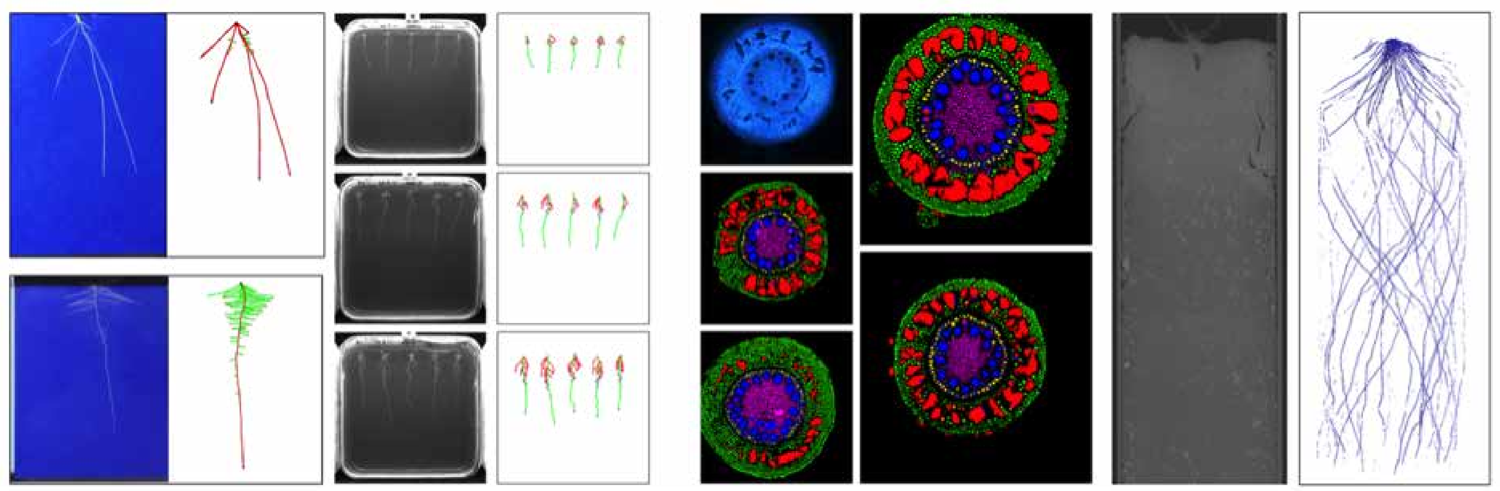
In the Computer Vision Lab at Nottingham we develop a wide range of computer vision and AI driven plant phenotyping and biological image analysis methods. We work closely with researchers in Plant Sciences at Nottingham and around the world to do this. The novel techniques produced in the lab are regularly embedded in high quality software tools and services which are made available to the wider community.

Prof Tony Pridmore is Professor of Computer Science in the School of Computer Science, where he is Director of Research and leads the Computer Vision Laboratory. His current projects focus on the development of novel image-based plant phenotyping methods and, increasingly, the creation and operation of large-scale phenotyping infrastructures. He is Director of the of the UKRI Technology Touching Life Network PhenomUK (www.phenomuk.net) and Associate Editor of both Plant Methods and Plant Phenomics.

Dr Andrew French holds a joint position in Computer Science and Plant Science. His BBSRC New Investigator project combines novel methods for plant biology visualisation on a light sheet fluorescence microscope (LSFM) with deep machine learning methods to help analyse the data. The challenge is to identify anatomical changes at the cell scale in very large, 3D timeseries datasets captured on machines such as the LSFM, where often only limited data



Outputs from the software developed in the Computer Vision lab

(in computer vision terms) is available. He is interested in applying new technology like virtual reality to, and developing AI approaches for, plant science.

Dr Michael Pound is a Nottingham Research Fellow in the School of Computer Science, and the Future Food beacon of excellence. His research focuses on applying computer vision and machine learning approaches to plant phenotyping problems. He focuses on the segmentation and identification of biological features in images. He recently led a project developing and releasing RootNav 2, a new tool to support high-throughput root phenotyping. His new BBSRC project "Learn from the best" will develop a new AI for decision making guided by biological experts. https://gtr.ukri.org/projects?ref=BB%2FT012129%2F1#/tabOverview

The Hounsfield Facility

The Hounsfield Facility, established in 2014, is a world leading multidisciplinary research centre which focuses on understanding plant and soil interactions and their responses to environmental stresses. It integrates scientists from across a wide spectrum of disciplines in the Schools of Biosciences, Computer Sciences, Mathematics and Engineering at the University of Nottingham. Our research employs state of the art imaging techniques such as X-ray Computed Tomography and Laser Ablation Tomography.

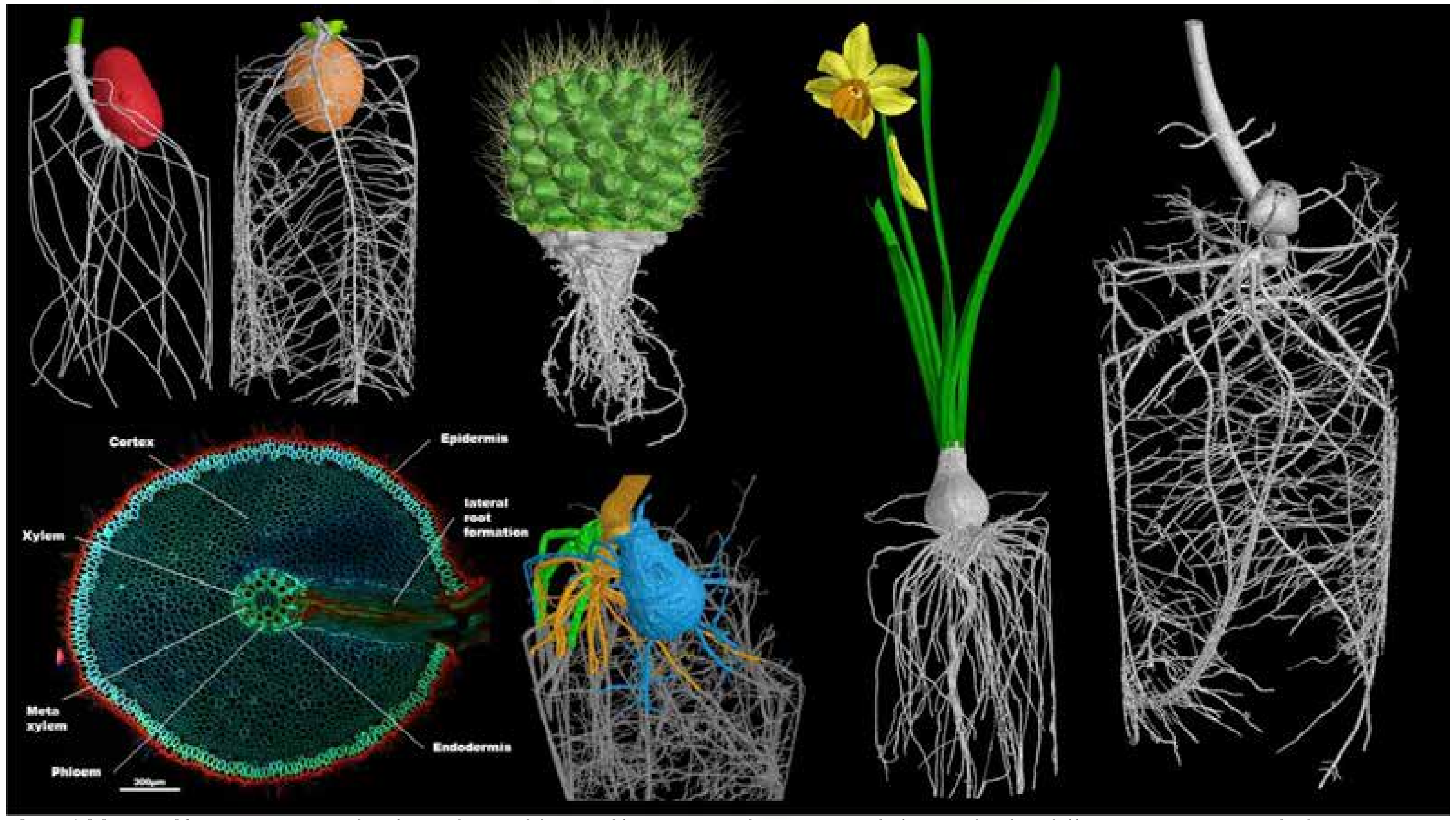
In addition to our academic research, we offer bespoke quantification and analytical services to both academic and commercial research projects. The Hounsfield Facility is home to some of the very latest in X-ray imaging research equipment housed in a state-of-the-art building with a fully automated greenhouse which is manned by a laser guided robot, needed to deliver the 1m long, 80kg samples to the largest scanner. Our equipment permits the quantification of materials over a range of spatial scales from <1µm to 150 µm. For further details: https://www.nottingham.ac.uk/microct).

The Hidden Half

The Hounsfield facility is host to a catalogue of plant root architecture called THE HIDDEN HALF https://www.nottingham.ac.uk/hiddenhalf/home.aspx. This was originally funded as a small project by the BBSRC to understand how plant root systems develop and their impacts on anchoring, storage of both food and nutrients and the explorative nature of plant species. This information is fundamental in the understanding of both food security and observing possible environmental threats for the future.

The Hidden Half website is now a directory of plant roots imaged at the Hounsfield Facility. A team of volunteers coordinated by Brian Atkinson manage and update the website content. There are currently seventeen species on the website, broken down into broad categories of Trees, Fruit, Vegetables, Grasses and Weeds, Crops, Arid, Flowers and Herbs. The website is free to access (data can also be requested for external use) with plans to expand the website with new species from across the plant kingdom as they are scanned or imaged at the Hounsfield Facility (Phase two currently has a further eight plants ready to be uploaded and there are currently thirty more plant species waiting to be processed). The aim is to have this as a world resource for public engagement and learning about the variety of diverse ways in which plant roots explore the hidden half of our world.

The use of X-ray Computed Tomography for in situ root architecture development combined with Confocal Microscopy, and Laser Ablation Tomography in imaging root anatomy gives us



The Hidden Half: Figure: Examples from the Hidden Half resource, showing top left to right the differences in rooting behaviour in potato varieties, Cactus root development, Daffodil, Bean. Bottom Left shows a cross section of grape vine root anatomy. Bottom Center; Freesia showing multiple root systems from one corm (blue is the original corm, orange is the stem root architecture and green showing the newly formed corm root system).

unique insight into how different plant species develop below ground in the hidden half. This is providing an understanding of how roots grow in the soil and identification of specific features of roots (e.g. root depth, thickness, angle or number of lateral roots). With respect to crop roots this could lead to improvements to allow for more efficient production of food with limited water or nutrient supply. X-ray CT is also a non-destructive technique which permits us to collect temporal information on how the root systems develop as they grow (4D imaging).

Nottingham Arabidopsis Stock Centre.

Sean Tobias May (Director)
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The Nottingham Arabidopsis Stock Centre (NASC) is a national and international capability resource that has been running successfully for 29 years. From small beginnings with only 200 seed stocks in 1991, NASC now has over a million stocks servicing a vigorous worldwide Arabidopsis community in collaboration with our sister centre ABRC in the USA. Labs from around the world donate seeds to NASC so they can concentrate on their scientific work, leaving the curation, management and validation of stocks to the centre. Stocks arrive as tens of thousands of seed donations every year and are preserved in specialist facilities dedicated to long-term storage and conservation. Our technicians receive these donations, store and regenerate low volume donations and process orders placed through our user-friendly on-line catalogue (http://arabidopsis.info).

The NASC resource is widely used and appreciated globally - More than 100,000 individual stocks per year for the last 5 years with a current peak of over 180,000 total seed tubes sent worldwide in one single year.

For nearly 20 years (since 1998) we have charged our users a nominal fee per stock to demonstrate both willingness and ability to supplement our grant from cost recovery income. This income has been used to employ temporary workers within NASC to (more than) match total staff numbers funded by the BBSRC. It means that our BBSRC funding is effectively subsidised for UK users by our foreign customers. The last 5 years have seen a sustained increase in user numbers from Asia, generating additional income for the staff needed to respond.

Our users include applied crop scientists, model organism researchers and computational systems biologists. Our job is to help plant scientists to receive essential arabidopsis materials in a cost effective, straightforward, consistent and efficient manner. We also have a strong track record and positive international partnerships with the US stock centre (ABRC), and The Arabidopsis Informatics Resource (TAIR).

The NASC Team

Wheat Research Centre

https://www.nottingham.ac.uk/wrc/home.aspx.

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The primary objective of the Nottingham BBSRC Wheat Research Centre (WRC) at Sutton Bonington is to transfer genetic variation for agronomically and scientifically important traits from wild and distantly related species into wheat and to distribute the germplasm generated world-wide for exploitation in breeding programmes and in scientific research in order to meet the needs of global food production. The WRC is one of the last centres in the world, and the only one in the UK, specialising in this work.

Recent research at the WRC has resulted in a major breakthrough, i.e. 1000 new genome-wide introgressions have been developed, with more being generated each year, from a range of species including *Amblyopyrum muticum*, *Triticum urartu*, *Triticum timopheevii*, *Aegilops caudata*, *Aegilops speltoides* and *Thinopyrum elongatum*. Hence, this work is, for the first time, facilitating the large scale and systematic transfer of genetic variation from the gene pools of the wild relatives to wheat.

To date trait analysis has only been undertaken on a limited number of the introgressions presently available for a small range of traits. However, this work has already revealed the presence of genetic variation for target agronomic traits, e.g. 20 introgression lines have been screened and resistance genes have been identified for three species of rust (yellow, stem and leaf) and Wheat streak mosaic virus (Fellers *et al* ., 2020 Crop Science.). These lines are presently being backcrossed into adapted US germplasm for future variety production. Researchers at Nottingham and CIMMYT screened 16 introgression lines and found two that carry genetic variation for increased photosynthetic capacity. Commercial partners have screened 22 introgressions lines and identified them all as either carrying potentially important genetic variation for resistance to yellow rust and/or lodging tolerance.

The WRC's research forms part of work package 3 in the BBSRC Designing Future Wheat Programme (DFW). It is underpinned by funding from the BBSRC and Nottingham University in addition to a range of other funders from both the public and private sectors. Key collaborators include JIC, the University of Bristol, Rothamsted Research, NIAB, CIMMYT, the USDA, ICARDA, the Indian Institute of Wheat and Barley Research, the Universities of Sydney/Adelaide, Chinese Academy of Sciences, Himachal Pradesh Agriculture University, the University of Pelotas and 8 members of the commercial sector.

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