The John Innes Centre magazine
Winter 2016/17

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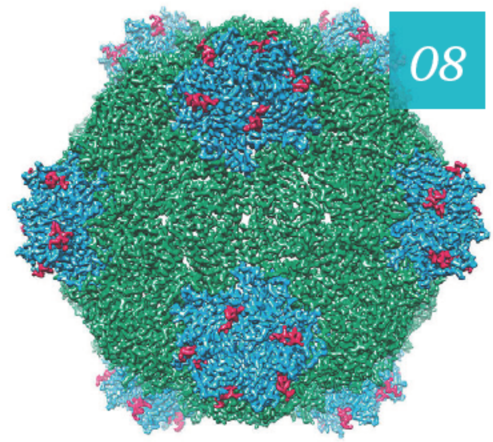
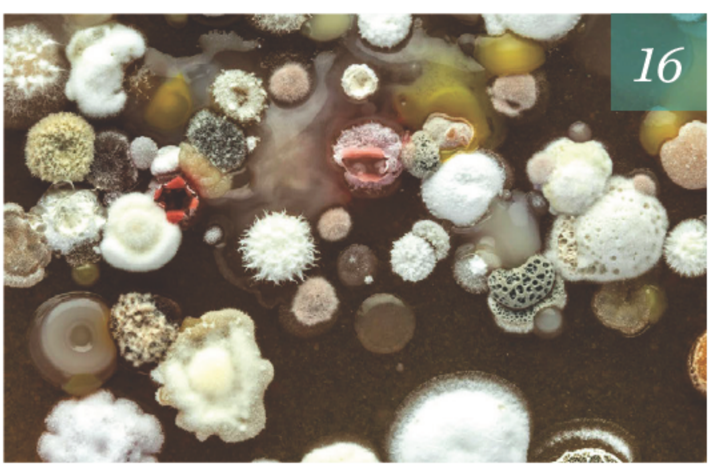
John Innes Centre
Unlocking Nature's Diversity

Advances





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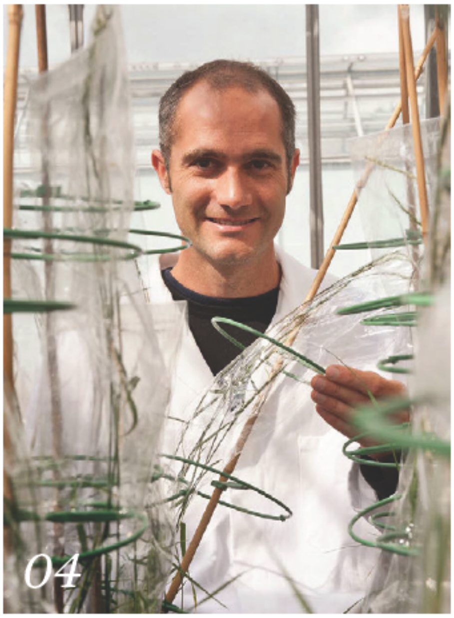

Cover images clockwise from top left: A Madagascar Periwinkle, the structure of an empty cowpea mosaic virus (CPMV), an ear of wheat, a South American leaf cutter ant, a culture of antinomycetes

Welcome to Advances

Professor Dale Sanders, Director of the John Innes Centre (JIC), introduces the second issue of the new-look Advances *magazine*

Plants and microbes are the source of a large proportion of the world's food and medicine. If we can understand how they work at a genetic and molecular level, we can harness their full potential. This is the focus of research at JIC. Our curiosity-driven scientific investigation aims to help the world produce more food more efficiently, and to increase options available to prevent and treat disease. This edition highlights some of JIC's research to address the global challenge of improved health and well-being.

Going viral (p8) describes Professor George Lomonossoff's development of a system to create and multiply empty virus-like particles in plants and how this is leading to the creation of new vaccines and a potential new diagnostic for the Zika virus.

In her profile interview (p6) Professor Sarah O'Connor talks about her research to understand the complex biochemical pathways in plants. These pathways are involved in making valuable compounds including vinblastine, which is used to treat several types of cancer.

Antimicrobial resistance (AMR) is a growing global crisis. The European Centre for Disease Prevention and Control (ECDC) estimated in 2009 that infections caused by multidrug-resistant bacteria are responsible for approximately 25,000 deaths in Europe annually. In addition healthcare costs and productivity losses were estimated at €1.5 billion. Our article on AMR (p16) explains how JIC is approaching this from different angles.

When I wrote the introduction to the first issue during the summer of 2016, the UK had yet to decide whether to retain our membership of the European Union. Six months later, the result of the referendum continues to reverberate across all UK sectors, including science. As a community, scientists must work with the UK Government to discuss how we can continue to conduct world-leading research in the long term. In her article *Beyond Brexit* (p15) Professor Cathie Martin – our lead faculty member on European Affairs – shares her ideas for the future of UK science.

A key message from Professor Martin's article is that science is an international endeavour. Scientists working at JIC have joined us from all over the globe. On pages 10-11 we illustrate the international nature of scientific careers. It is crucial that scientists from all over the world can work and live in the UK and we will do our utmost to make this case.

In *Awards and achievements* (p18) we demonstrate how our scientists continue to lead in their fields, attracting awards, grants and leadership positions. As an institute, JIC has been recognised as the UK's most collaborative research performer in the life sciences according to Nature Index (http://go.nature.com/2jEbgT). I am also glad to report that our international collaborations continue to go from strength to strength.

We reached a milestone in our partnership with the Chinese Academy of Sciences (CAS) when we opened two new CEPAMS (Centre of Excellence in Plant and Microbial Science) laboratories: one in Shanghai and one in Beijing. Find out more on p14.
Our scientific connections with China go back a long way. For this edition's alumni interview (p19) we had the pleasure of interviewing Professor Zhihong Xu, one of the first visiting scientists from China to work in research institutes and universities in the UK.

We were pleased to be the first UK institute to provide advanced science training placements for the African Women in Agricultural Research and Development (AWARD) intitiative. Find out more on p12.

These are exciting times at JIC and we are happy to share our progress with you. I hope you enjoy reading this issue.

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for more information or follow us at @JohnInnesCentre

Science Research Spotlight

Here's a round-up of recent research from the John Innes Centre

'Chemical origami' to generate customisable chemicals from plants

Professor Anne Osbourn and her team have discovered a new and valuable mutated version of the triterpene synthase enzyme SAD1, which folds linear molecules into cyclic triterpene scaffolds with four carbon rings instead of the typical five. When used in yeast the mutated SAD1 enzyme also produces triterpenes containing more oxygen atoms than normal as it can utilise a different linear starting material. SAD1 is part of an enzyme toolkit that the team is using for their pioneering project to construct a 'triterpene machine' to custom-build large, cost-effective quantities of triterpene molecules for diverse potential medical and agricultural applications.

+ *The paper* ***A conserved amino acid residue critical for product and substrate specificity in plant triterpene synthases*** *was published in the journal The Proceedings of the National Academy of Science.*

DOI: 10.1073/pnas.1605509113

JIC scientists solve 60-year-old Septoria mystery

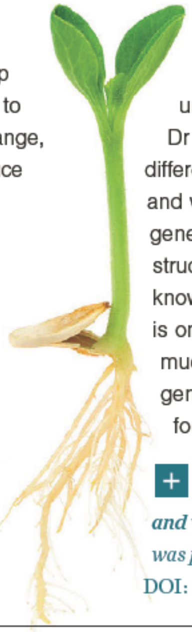
New research by scientists at JIC explains why plant breeders have found it difficult to produce wheat varieties that combine high yield and good resistance to Septoria, a disease in wheat. Using a technique called association genetics, Professor James Brown and Dr Lia Arraiano analysed resistance and susceptibility to Septoria in wheat varieties grown in the UK between 1860 and 2000 and found the gene with the biggest effect on increasing susceptibility is closely linked to the one that increases yield and grain size. "We discovered where the small region of the genome that increases both Septoria and yield came from. We traced it back to a variety called Heines Peko, which was used to breed for yield and rust resistance in the late 1950s."

Heines Peko was crossed with Cappelle Desprez, the major wheat variety in Britain at the time with all modern wheats bred in Britain now descended from it. Professor Brown suggests that as wheat breeders selected for higher yield, susceptibility to Septoria hitch-hiked along with it. "My group is now trying to find out if the connection between the two traits can be broken."

+ *The paper* ***Sources of resistance and susceptibility to Septoria tritici blotch of wheat*** *was published in the journal Molecular Plant Pathology.*

DOI: 10.1111/mpp.12482

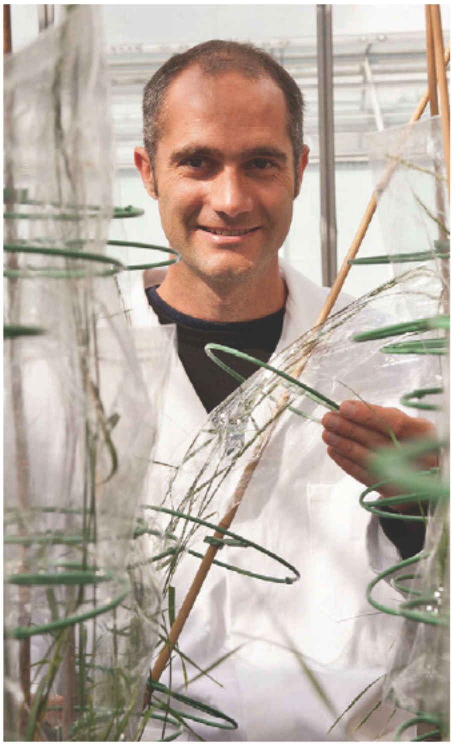
New technique to track down valuable genes



Dr Brande Wulff and his team have created an innovative technique that makes it easier to pinpoint genes in wheat and barley genomes. The genes of interest could be used to develop improved crop varieties better able to cope with the effects of climate change, new pests and diseases and produce higher crop yields to feed a growing human population.

Locating the gene for a particular trait can be like trying to find a needle in a haystack.

Dr Wulff's new technique – MutChromSeq – involves subjecting seeds from a plant with the interesting trait to a chemical that disrupts their DNA. Any mutants that have lost the trait are identified by screening. A technique called chromosome flow sorting is used to eliminate the chromosomes we know do not contain the gene of interest. Then the sequence of the mutated chromosomes can be compared with that of the unmutated chromosome.



Dr Wulff said, "By looking for the differences in sequence between the mutated and wild-type chromosomes, we can identify genes without knowing anything about their structure beforehand. So long as we already know which chromosome a particular gene is on, this technique is going to make it much easier to clone any wheat or barley gene of interest, which is great news for researchers!"

*+ The paper **Rapid gene isolation in barley and wheat by mutant chromosome sequencing** was published in the journal Genome Biology.*
DOI: 10.1186/s13059-016-1082-1

Rice yield boosted by 50 per cent

Dr Tony Miller, along with collaborators from Nanjing Agricultural University, has developed rice crops with an improved ability to manage their own pH levels, enabling them to take up more nutrients from soil and increase yield by up to 54 per cent. Rice contains a gene called OsNRT2.3, which creates a protein involved in nitrate transport. This gene makes two slightly different versions of the protein: OsNRT2.3a and OsNRT2.3b.

Following tests to determine the role of both versions, Dr Miller's team found that OsNRT2.3b is able to switch nitrate transport on or off, depending on the internal pH of the plant cell. When this 'b' protein was overexpressed in rice plants they were better able to buffer themselves against pH changes in their environment. This enabled them to take up more nitrogen, as well as more iron and phosphorus. These rice plants gave a much higher yield of rice grain (up to 54 per cent more), and their nitrogen use efficiency increased by up to 40 per cent.

*+ The paper **Overexpression of a pH-sensitive nitrate transporter in rice increases crop yields** was published in the journal The Proceedings of the National Academy of Science.*
DOI: 10.1073/pnas.1525184113

JIC scientists create new training resource to break down barriers to wheat research

Scientists from Dr Cristobal Uauy's laboratory at JIC have developed a new open access online wheat training hub to support researchers currently working on wheat or hoping to make the transition to work on this important crop.

Wheat is one of the most widely cultivated crops in the UK and worldwide. It is estimated that global cereal production must double by 2050 to feed the world's growing population.

Wheat is generally considered as a difficult plant to work with due to its relatively long generation time and lack of genomic resources. These barriers often discourage scientists from working on wheat compared with more established model plant species such as Arabidopsis.

In the last few years, wheat laboratories around the UK and the world have significantly lowered these barriers. However, access to this information is usually scattered across multiple sites, making it difficult to find. In addition basic skills training, such as how to grow and cross wheat and essential knowledge on wheat terminology, is not readily found. The training hub provides essential, step-by-step information on experimental protocols, wheat cultivation, and up to date guides to a wide range of genomics tools, all of which can provide a solid foundation from which to carry out wheat research. The hub can be found at www.wheat-training.com.

The Uauy laboratory is funded by the BBSRC and the International Wheat Yield Partnership.

Mining the power of plants

"I can't move to England!" said Professor Sarah O'Connor from across the pond. Professor Anne Osbourn had just suggested she apply for a job at JIC. Despite her initial misgivings, for Professor O'Connor – then an Associate Professor of Chemistry at the Massachusetts Institute of Technology – the seed of adventure was sown. Nearly six years later and a JIC project leader in Biological Chemistry, Professor O'Connor is here to stay and is awaiting indefinite leave to remain

Professor Sarah O'Connor is interested in understanding the biosynthetic pathways giving rise to "specialised metabolites" in plants – natural compounds with important applications in the pharmaceutical and agricultural industries – but that wasn't always the case.

"I had some really great chemistry professors in high school; I was good at the subject, and really enjoyed it, so that's what I decided to do at university," she reminisces. "But then I started an undergraduate research project in physical chemistry and hated it!"

Switching to synthetic organic chemistry, Professor O'Connor graduated and found a PhD advisor working on a biological problem she was interested in: how glycosylation – adding sugar groups to proteins – affects protein structure and function. "Like many PhD students, I felt overwhelmed by research at times, but I just couldn't think of anything else I'd enjoy more than a research career!" Professor O'Connor's interest shifted to exploring the roles of the enzymes catalysing the structural changes in the proteins – specifically in plants. "I found I needed to become better acquainted with plant biology," she said, "and that was hard to do in a chemistry lab. It was that which led to me calling Professor Anne Osbourn for advice – and soon after I realised that if I was going to make progress in this field of research, the John Innes Centre was the best place to do it."

Much of Professor O'Connor's recent work has used *Catharanthus roseus* – the Madagascar Periwinkle – as a model organism. Not just a pretty, ornamental flower, this plant is also known for its production of vinblastine; a compound used as a chemotherapeutic agent to treat several types of cancer.

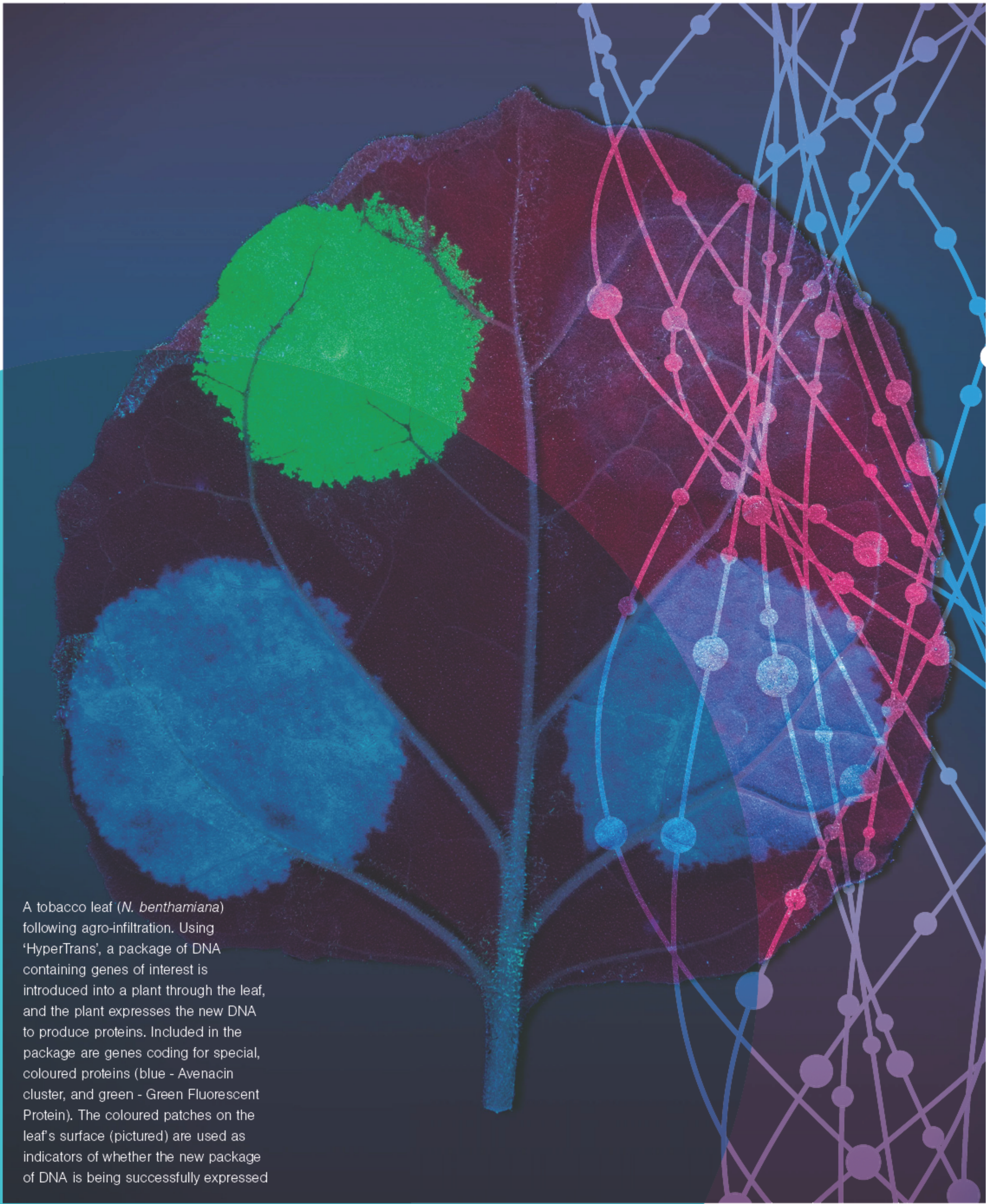
"My research seeks to understand the complex biochemical pathways involved in making vinblastine. We want to find ways to produce this compound more quickly, cheaply, and in large quantities for industry, but we also want to know if we can manipulate those pathways to improve the pharmaceutical properties of specialised metabolites, or even find new metabolites with useful properties."

As well as the Madagascar Periwinkle, the mint plant is also yielding some interesting findings. "With collaborators, we're looking at over 50 different plants in the mint family – these don't make vinblastine, but they do make compounds called iridoids, which are made by a related biosynthetic pathway. Through these studies, we're discovering more about the evolutionary contexts of specialised metabolite production, but we're also learning more about how to make iridoids," she explained. "Naturally occurring iridoids have been shown to have anti-inflammatory effects; they can help protect the heart, liver and nerves; they have anti-cancer and anti-microbial activities, they can help regulate blood sugar and fat levels... there is so much potential! We recently discovered an enzyme responsible for making iridoids – this was completely new chemistry, so it was exciting!"

"Ultimately, we want to transfer our knowledge to lots more plants," Professor O'Connor said. "Plants are

a goldmine for natural compounds and I hope our research will help make the chemistry of plants much more accessible to industry. Discovering these compounds and finding ways to produce them in large amounts could help us develop medicines for a whole range of conditions that are cheaper, which work better, and which have fewer side effects than ones we currently use. Maybe we'll even discover compounds to make completely new medicines for currently untreatable diseases?"

> Discovering these compounds could help us develop medicines for a whole range of conditions which have fewer side effects



A tobacco leaf (*N. benthamiana*) following agro-infiltration. Using 'HyperTrans', a package of DNA containing genes of interest is introduced into a plant through the leaf, and the plant expresses the new DNA to produce proteins. Included in the package are genes coding for special, coloured proteins (blue - Avenacin cluster, and green - Green Fluorescent Protein). The coloured patches on the leaf's surface (pictured) are used as indicators of whether the new package of DNA is being successfully expressed

Going viral

A few years ago, when Professor George Lomonossoff and then-PhD student Frank Sainsbury first developed the CPMV-HT system, they could only have imagined the applications that this plant-based protein expression system would have

The system – now refined and patented under the name 'HyperTrans' – uses a modified, non-replicating version of cowpea mosaic virus to introduce foreign DNA into plant cells. This causes those plant cells to express foreign proteins in high quantities.

"HyperTrans can turn plants into factories to produce large quantities of potentially any protein we like," said George Lomonossoff, a Professor in the Department of Biological Chemistry at JIC. "One of the most exciting applications is its ability to produce virus-like particles, or VLPs. Essentially, these are 'empty' shells of viral protein that lack the infectious genetic material normally found inside the shell. The system is already being used by a North American company to produce flu vaccines – to the immune system, the VLP still looks like the influenza virus, so it raises an immune response that provides immunity against the real flu virus."

Professor Lomonossoff has now set his sights on eradicating polio. In some cases, poliovirus can cause paralysing and limb-deforming poliomyelitis. It was once common, but an effective, worldwide vaccination programme has succeeded in almost completely eradicating this disease from humanity – so why is the World Health Organisation funding efforts to develop yet another polio vaccine? "The existing oral poliovirus vaccine [OPV] is incredibly effective," said Professor Lomonossoff, "but because it uses a live attenuated virus, it retains the ability to revert back to the dangerous form. It does this in about 100 people every year. I'm part of a large research consortium that is developing next-generation polio vaccines that, we hope, will eradicate polio from the world for good."

Colleagues at the National Institute for Biological Standards and Control laid the groundwork for this new vaccine by screening poliovirus mutants until they found one that is stable without its genetic material, even under very high temperatures. "A PhD student in my laboratory, Johanna Marsian, then took this knowledge to create a highly stable yet completely genome-free polio VLP in plants," said Professor Lomonossoff. "Early mouse experiments indicate that this VLP provides as-good if not better immunity than the current polio vaccine. What's more, HyperTrans offers a quick, cheap way of making very large quantities of the vaccine suitable for large-scale pharmaceutical production."

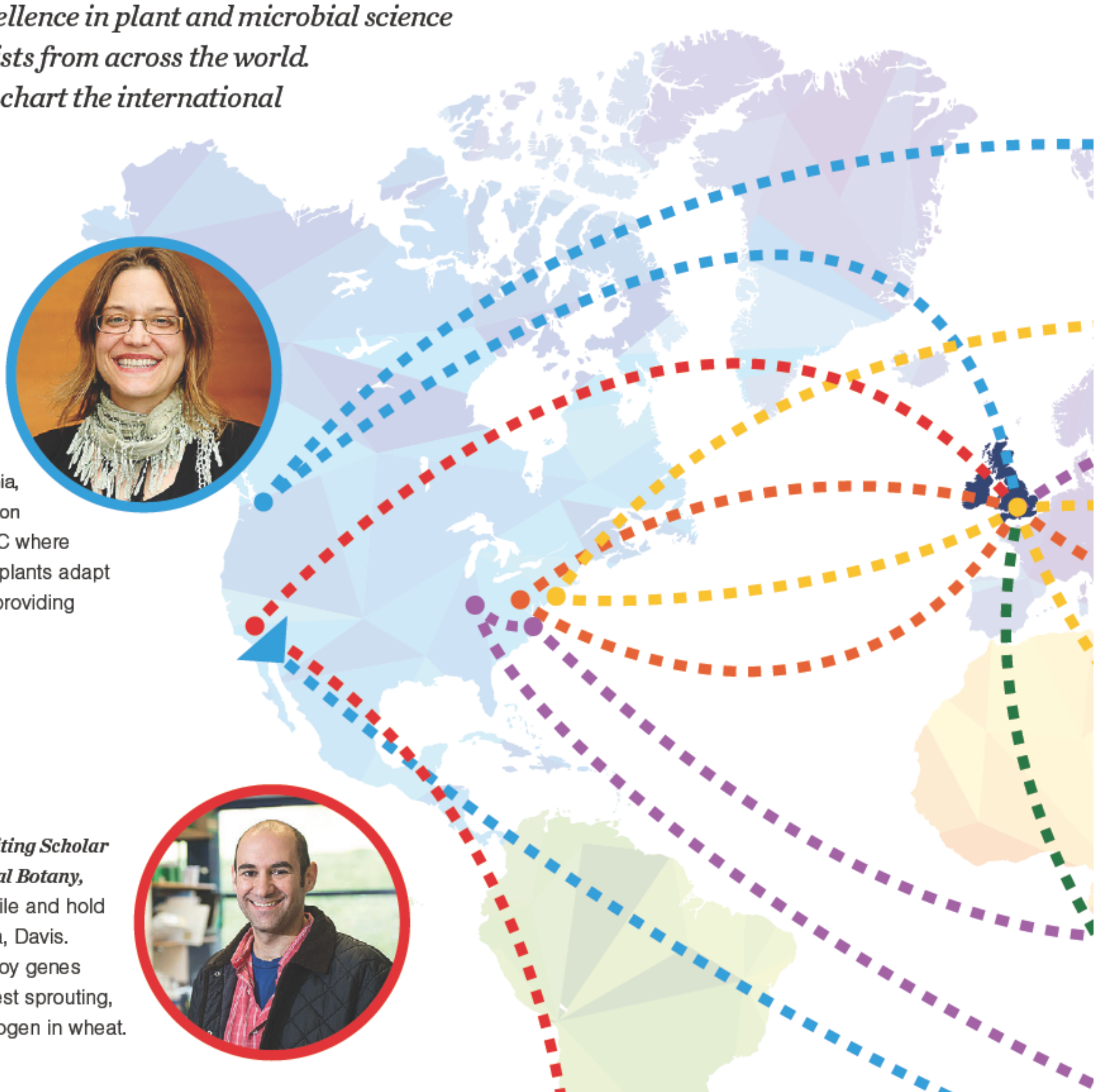
The HyperTrans system also looks set to revolutionise the diagnosis of another headline-hitting virus: Zika, the mosquito-borne disease affecting parts of Brazil. "A problem with Zika," Professor Lomonossoff said, "is that the virus and its early symptoms look very similar to other viruses, like Dengue, which are transmitted by the same mosquito species. However, if we are to give people the right medical care, we need to know which virus they have been infected with. With my postdoc Eva Thueneman, I'm using HyperTrans to develop harmless VLPs that mimic the live Zika virus – these might be used to make cheap blood test kits that can accurately distinguish Zika from other related viruses."

Interest in the emerging and growing field of plant-based chemical production has led to the formation of the International Society for Plant Molecular Farming, of which Professor Lomonossoff is now the second President. "Myself and other researchers who worked together in this area wanted to establish a more formal way of 'keeping the flame alive' after our respective projects came to an end. The ISPMF holds a conference every two years and publishes a newsletter, which you can download from our website www.societyformolecularfarming.org/".

> This VLP provides as-good if not better immunity than the current polio vaccine

Science is global

JIC is a global centre of excellence in plant and microbial science that attracts the best scientists from across the world. Here, some of our scientists chart the international career paths that have led them to work at JIC



Dr Jodi Lilley
USA

I facilitate peer-partnerships for scientific capacity building in the UK and Africa. While doing my degree in California, I studied in Tasmania, Australia. I then did my PhD in Washington State. Right after my PhD I came to JIC where I am investigating how pea and bean plants adapt their root structure to house nitrogen-providing beneficial bacteria.

Dr Cristobal Uauy
Chile

I am a Project Leader at JIC and a Visiting Scholar at the National Institute of Agricultural Botany, Cambridge. I studied Agronomy in Chile and hold a PhD from the University of California, Davis. My research aims to identify and deploy genes involved in wheat grain size, pre-harvest sprouting, and resistance to the yellow rust pathogen in wheat.

Ngoni Kangara
Zimbabwe

Before coming to JIC I worked as a project manager for NGOs and the seed industry in Zimbabwe. My research at JIC identifies proteins produced by the fungus wheat stem rust during its invasion of wheat cells. This PhD training gives me an excellent opportunity to pursue my interests in plant pathology.

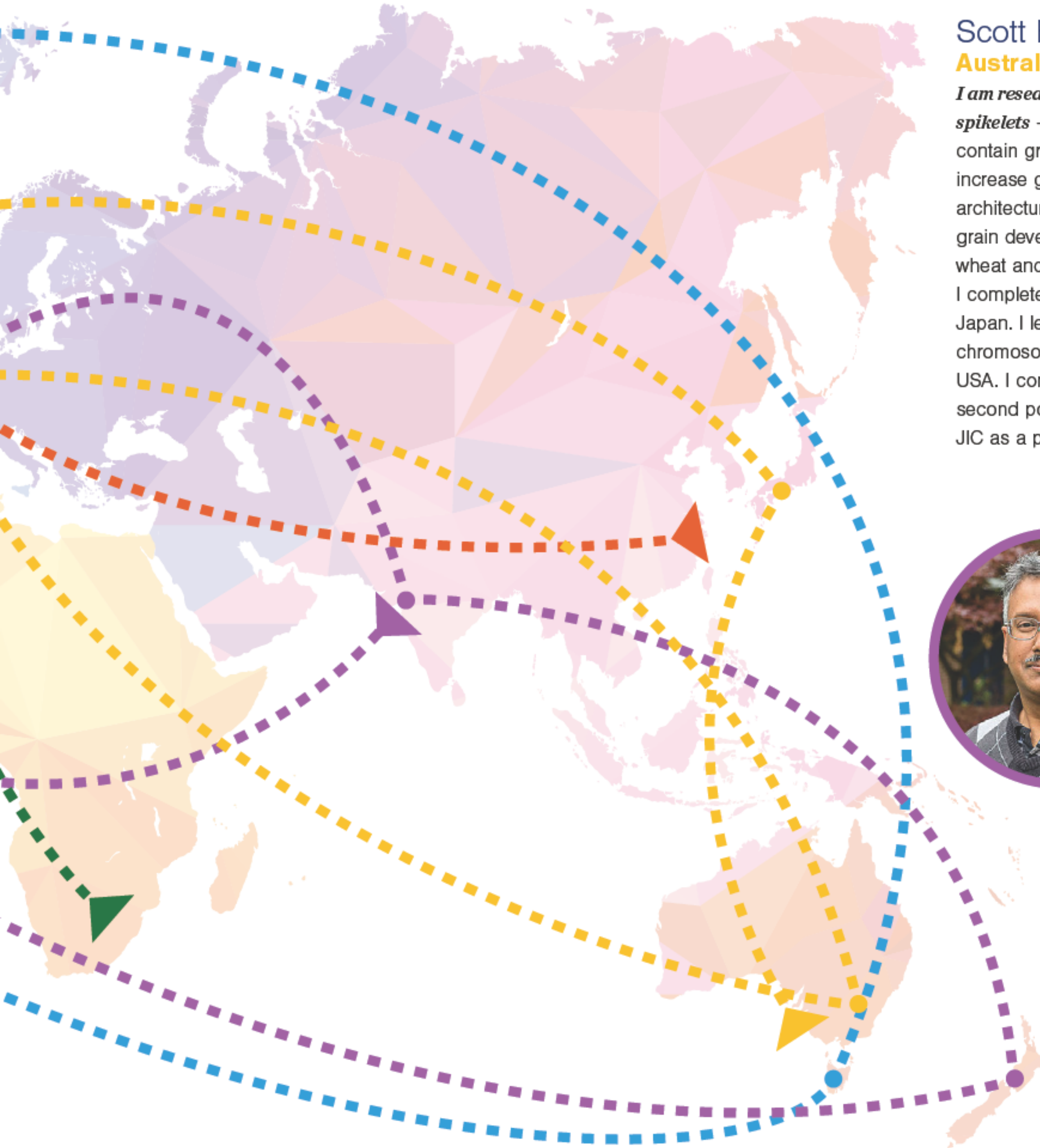
THERE ARE
41
NATIONALITIES OF STAFF AT JIC

Yiliang Ding
China

I am investigating how to regulate RNA biology processes in living cells by altering RNA structure. I aim to reveal new mechanisms for gene regulation. I completed my degree in Shanghai China and my PhD at JIC. I was a post-doc scholar at Penn State University, USA before returning to JIC as a project leader in 2014.

Scott Boden
Australia

I am researching the development of wheat spikelets – the reproductive branches that contain grain-producing florets. My aim is to increase grain yield by optimising spikelet architecture and the duration of flower and grain development in major crops including wheat and barley. During my PhD I completed an exchange at Kyoto University, Japan. I learned a technique to investigate chromosome structures at Cornell University, USA. I completed my first post-doc at JIC, my second post-doc in Australia and returned to JIC as a project leader in 2015.



Dr Abhimanyu Sarkar
India

I work on a joint Indo-UK project to eliminate a neurotoxin from grasspea (Lathyrus sativus), a hardy legume grown as an insurance crop by poor farmers in Asia and Africa. Before joining JIC, I worked in New Zealand on white clover, an important forage legume. I have a PhD from the USA and a Masters and a Bachelor's degree from India.

African Women in Agricultural Research and Development

JIC became the first UK host institution for African Women in Agricultural Research and Development (AWARD) fellows

AWARD is a career-development programme that equips female agricultural scientists from across sub-Saharan Africa with advanced science and leadership skills. AWARD aims to boost Africa's agricultural gains through supporting world-class research and development. As part of the programme, fellows are able to spend time at leading international research facilities to strengthen their scientific skills. In August 2016, JIC became AWARD's first host institution in the UK.

Through establishing networks of global collaborations and promoting the flow of information and experience, programmes like AWARD can bolster efforts to address challenges in global agriculture. By supporting AWARD, JIC hopes to equip African scientists with the skills and experience necessary to fulfil the massive potential for scientific advancement in Africa. JIC has been able to support the AWARD programme through BBSRC funding awarded to JIC as a result of winning the 2013-2016 Excellence with Impact competition.

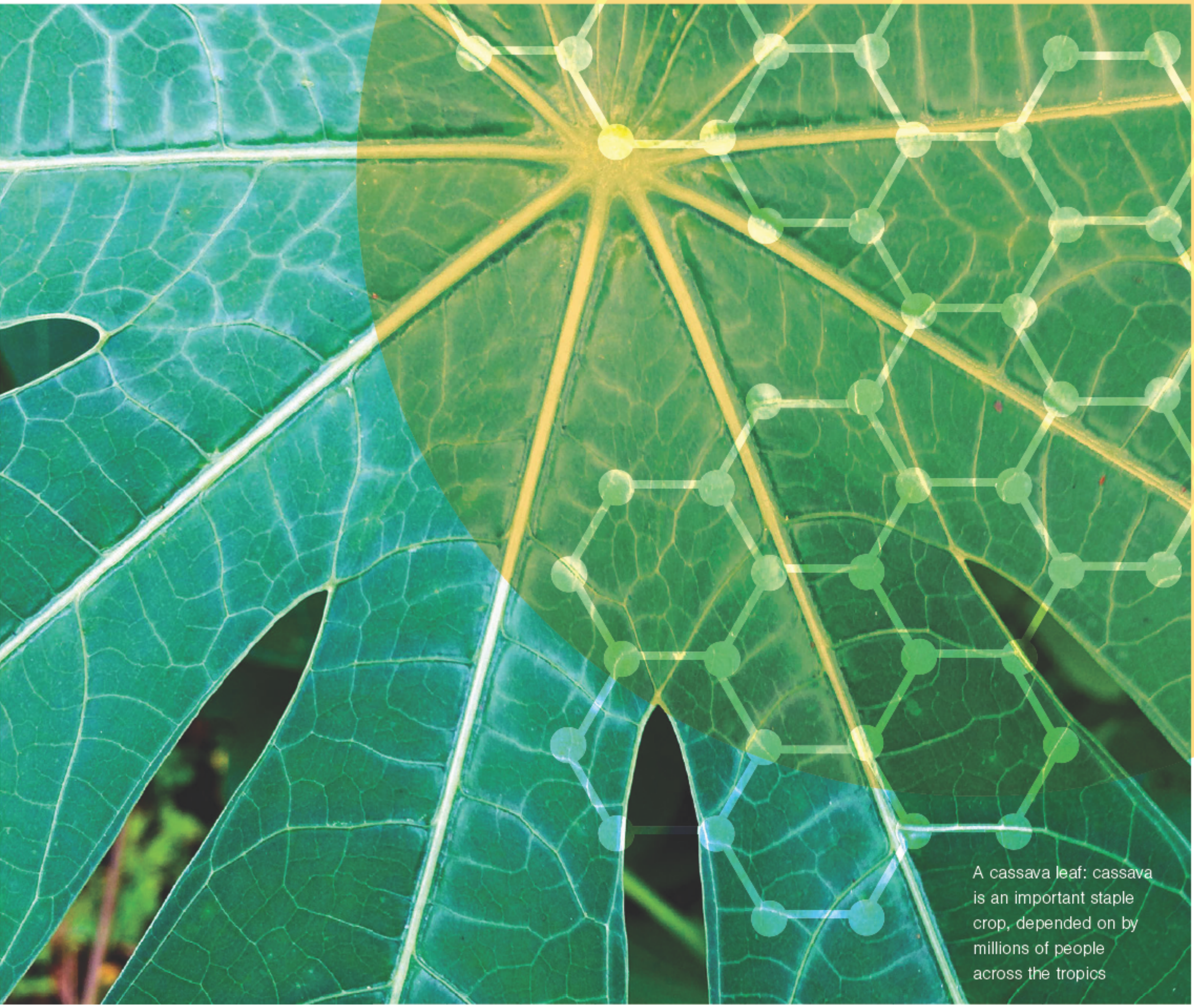
Dr Rose Kigathi of Pwani University, Kenya arrived at JIC in the autumn of 2016 to work with Dr Diane Saunders on the emergence of new wheat stem rusts in East Africa using genomic and bioinformatic approaches.

Dr Angela Eni from the Covenant University, Nigeria, worked with Professor George Lomonossoff from July to October 2016, learning techniques that can be applied to her research on protecting cassava plants from viruses to improve the productivity of this staple African crop.

Dr Rose Kigathi (pictured left) writes about her AWARD fellowship and her research placement at JIC.

When I returned to Kenya after my PhD I was looking for a way to use my experience to improve livelihoods of rural communities. I also wanted to connect with other scientists working in agricultural research and development in Africa. When I heard about the AWARD fellowship, I realised it would provide these opportunities and I applied. My experience with AWARD has been great. One of the highlights so far was training on participatory rural appraisal. This was a technique I had only read about previously but received first-hand experience through AWARD training. The AWARD career planning tool (Purpose Road Map) also helped me to plan my career path and identify my strengths and "gaps", which I could build upon to reach my career goals.

The Advanced Science Training (AST) is one of the key components of the AWARD fellowship that I really value. These competitive and sought-after placements aim to strengthen a



A cassava leaf: cassava is an important staple crop, depended on by millions of people across the tropics

fellow's research and scientific skills. My work aims to rapidly generate solutions for problems facing agricultural production by understanding how individual organisms function within populations and their environment using both laboratory and field studies.

I chose to develop my bioinformatics knowledge for my AST because I realised these skills will be essential. I was delighted to be placed working with Dr Diane Saunders, a joint research fellow at JIC and Earlham Institute. I hope to establish long-term working relationships with Norwich Research Park (NRP) researchers and help connect scientists working in the UK and Kenya. What I like is the collaborative research culture and I hope to learn from the NRP community's commitment and focus on soft skills development through continued learning and training.

Pictured right: *Dr Angela Eni worked with Professor George Lomonossoff to develop techniques for improving productivity of cassava*

New beginnings in UK and China partnership

Joint venture will address the global challenges of food security and improved human health and well-being

CEPAMS

The John Innes Centre's international collaboration with the Chinese Academy of Sciences (CAS) reached an important milestone in the autumn of 2016 with the opening of two new laboratories in China that will house the Centre of Excellence for Plant and Microbial Sciences (CEPAMS).

The first laboratory was opened in Shanghai in September by UK Minister of State for Universities, Science, Research and Innovation, Jo Johnson and Dr Cao Dianwen, Deputy Director for International Collaboration at CAS. The second was opened in early November in Beijing by CAS Vice President Zhang Yaping and Martyn Roper, Deputy Head of Mission at the British Embassy.

Along with CEPAMS' third campus located at JIC in Norwich, both new laboratories will use excellent science to tackle the global challenges of food security and improved health and well-being. CEPAMS will be recruiting scientists over coming months to lead research groups in the new laboratories.

Collaborative research projects to address the global challenge of food security will focus on areas such as improving crop yields, decreasing the threat from crop pests and

pathogens and reducing the need for artificial fertiliser. Research to improve human health includes two projects related to the study of Chinese traditional medicines. The first CEPAMS Group Leader, Yang Bai (pictured left), took up his position in May 2016, joining from the world-renowned Max Plank Institute in Cologne. The Bai laboratory – housed within the Institute of Genetics and Developmental Biology in Beijing – investigates microbes associated with healthy plant growth.

The CEPAMS partnership was established in 2014 with funding from the UK Biotechnology and Biological Sciences Research Council (BBSRC) and the Chinese Academy of Sciences (CAS). It brings together the John Innes Centre (UK), the Institute of Genetics and Developmental Biology (Beijing) and the Institute of Plant Physiology and Ecology (Shanghai).

JIC was among the first UK institutes to welcome Chinese researchers working abroad in the late 70s and 80s. See our Alumni interview with Professor Zhihong Xu (p19) who worked at JIC in 1979.

Science Minister Jo Johnson

"Greater international collaboration is key to solving real-life tangible challenges we face around the world and this new centre is testament to our scientific partnership with China. It will bring together the brightest minds from the UK and China to improve crop production for the world's growing populations."

Beyond Brexit

JIC's lead faculty member on European affairs, Professor Cathie Martin, gives her viewpoint on the future of UK science outside of the European Union

The science of genetics was born in the first years of the 20th century when a British academic was introduced to the forgotten discoveries of an Austrian monk by a Dutch botanist. Although over 110 years old, this is a good example of the importance of science as an international endeavour. The academic was William Bateson, the person who first coined the term "genetics" and also the first Director of the John Innes Centre.

International collaborations are an essential part of excellent science. They bring together multidisciplinary teams to address problems from different but complementary perspectives providing the foundations for real innovation. The majority of scientific publications from the UK are now co-authored by at least one international partner. Many of the challenges facing our societies are global, requiring collaborative, multidisciplinary, international scientific responses. Today, JIC is the UK's most collaborative research performer in the life sciences according to Nature Index.

Science and the EU

The majority of British scientists favoured remaining in the EU, because they realised the very real benefits of EU support for projects that have shaped the ways fundamental science is applied, as well as programmes supporting individual excellence. The free movement of "ideas" has been described as the fifth fundamental freedom of the European Union. According to a recent House of Lords Science and Technology Committee report, the UK contributed nearly £4.3bn for EU research from 2007 to 2013, but received nearly £7bn back over the same period.* EU research programmes have provided great success stories over the last 30 years and Brexit will cause a major shift for UK science.

Beyond Brexit

We will need to ensure we continue as a world leader in scientific research and innovation. We have the opportunity to create a vision and framework for an internationally connected, competitive British science base, based on the following guiding principles:

Excellent science is international science – we should develop incentives to make the UK more attractive to scientists and level the playing field for excellent scientists wishing to live and work in the UK. Such colleagues expand our perspectives and scientific capabilities and their contributions to science and our economy drives economic growth.

Be at the heart of global science – we should invest in science diplomacy and build a global network of bilateral and multilateral science initiatives and funding mechanisms to include links with EU programmes like Horizon 2020.

Not all "European" programmes are "EU" programmes – we should continue to engage with intergovernmental mechanisms that enable collaboration among willing European countries and that sit alongside EU mechanisms (eg Joint Programming Initiatives, EMBO Fellowships, European Research Area Networks, COST Actions, etc).

Associated status on science is worth the investment – every scientist understands the benefits of the EU framework programmes (collaborative and economic value, attraction of the best scientists) and these are particularly strong for the European Research Council (ERC) awards. Negotiating some form of association with H2020, and programmes beyond, is definitely in our interests.

It is widely accepted that science is a global endeavour. We can and should take steps to support the international foundations of UK science beyond Brexit. By investing more in global networks and working in new ways with the EU and the wider international community we can make sure we continue to build on one another's scientific advances, contribute to economic growth and collaborate to address the grand challenges of our time.

** The financial contributions from the UK to EU science and research cannot be determined definitively because the UK's contribution to the EU contains no formally hypothecated amount for R&D. The contribution can, however, be inferred by calculating the proportion of EU expenditure devoted to R&D and assuming that the UK contribution includes the same proportion of spend.*

Fighting back against antimicrobial resistance

Antimicrobial resistance (AMR) is currently one of the greatest threats to global health. The John Innes Centre is working to address this challenge using a range of innovative approaches

Antimicrobial medicines are compounds used to destroy or disable disease-causing pathogens such as bacteria and fungi. But pathogens are constantly changing and evolving to overcome the antimicrobials currently available, making it harder to successfully treat infections. The threat of AMR has been exacerbated by the widespread misuse of antibiotics in humans and animals, which increases the pressure on pathogens to evolve. There is a desperate need to find new sources of antimicrobial agents and develop new ways to kill or disable pathogens.

Here are seven ways that scientists at the John Innes Centre are fighting back against antimicrobial resistance:

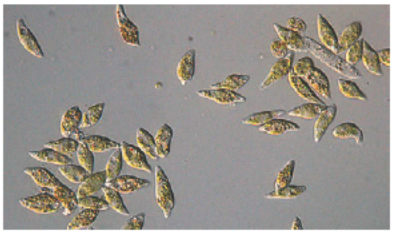
Actinomycetes: a diverse group of bacteria that are the major source of clinically useful antibiotics worldwide

1: PREVENTION When bacteria infect a plant or a human they first must move across the host's outer surface to a site of infection. Without this migration, the bacteria find it difficult to enter the host and so are less able to infect. Work by ***Dr Jacob Malone's*** (right) group discovered that, in *Pseudomonas*, this migration is compromised when RimK, a key protein, is removed. RimK is suggested to be a key component in the response of bacteria to their surroundings by controlling the production of a range other proteins. Removing RimK immobilises the bacteria, reducing the chance of infection. Also by disabling rather than killing it, the pressure on pathogens to evolve and develop resistance is reduced.

2: DIAGNOSIS Diagnostic tests for determining the cause of illnesses are typically slow, and patients that require urgent treatment may not be able to wait for results to return from the laboratory. This can lead to incorrect treatment of viral or fungal infections with antibiotics, which exacerbates the progression of antimicrobial resistance. A new diagnostic tool, developed by JIC scientist ***Professor Rob Field*** and ***Prof David Russell*** from the UEA for their spin-off company Iceni Diagnostics, could help to prevent this problem in the future. Their diagnostic device consists of 'dipsticking' a sample into a sugar solution containing gold. By a rapid change of colour the device can indicate the presence of bacteria in a sample. If brought to commercial availability this new tool will allow quick and accurate diagnoses, and reduce improper prescription of antibiotics.

3: FUNCTIONALITY DNA topoisomerases are enzymes that affect the coiling of DNA molecules. Sections of DNA can be coiled or uncoiled to control how the genes in that section are expressed. One example is DNA gyrase, an enzyme found in plants and bacteria that carries out essential DNA coiling functions without which these organisms cannot function properly. ***Professor Tony Maxwell's*** group are seeking to further understand how DNA topoisomerases work, and the processes they are involved in, and use this knowledge to inform the development of new antimicrobials that target topoisomerases in bacteria.

4: POTENTIAL *Euglena gracilis*, a single-celled algae (below), has a huge genome comprising some 32,000 genes or more. ***Professor Rob Field's*** group recently discovered that among these is a whole host of new, unclassified genes that have massive potential for the production of natural compounds. Euglena is already known to produce natural products including vitamins, essential amino acids and a sugar polymer that is reported to have anti-HIV effects. These findings have the potential to lead to the discovery of new antimicrobial compounds.



5: DISCOVERY South American leaf cutter ants (right) tear through the rainforest collecting leaves and returning them to their nest. The ants use the leaves to cultivate farms of fungus, and it's this fungus that's their main source of food. In order to protect their fungus crops against unwanted pathogens, the ants have developed a close relationship with a type of bacteria called actinomycetes. These bacteria, which the ants harbour on their bodies, produce a range of antimicrobial compounds that protect the fungus farms against infections. Along with collaborators at the UEA, ***Professor Barrie Wilkinson's*** group is studying the actinomycetes used by leaf cutter ants in the search for new antimicrobial compounds.

6: GENOME MINING Early sequencing experiments on actinomycetes revealed a huge, unexpected genetic potential to produce new natural compounds. The improvement in speed and accuracy of Next-Gen sequencing techniques has provided new opportunities to explore the genomes of actinomycetes and to exploit their metabolic potential for novel compound production. At JIC the groups of ***Professor Barrie Wilkinson*** and ***Dr Andrew Truman*** (right) are using genetic methods to find and activate previously uncharacterised metabolic pathways to reveal new antimicrobial compounds. The next generation of antimicrobials could be hidden within the genomes of this group of bacteria, just waiting to be discovered.

7: BIODIVERSITY The Atacama Desert (above), one of the oldest and most arid deserts on Earth, seems an unlikely place to find flourishing microbial populations. However, recent studies have found a rich diversity of microbial life there, including a particular abundance of a group of bacteria called actinomycetes, which are responsible for producing a large proportion of the microbial-derived antimicrobials worldwide. Emeritus ***Professor Mervyn Bibb*** has been 'bioprospecting' the Atacama Desert on the hunt for new strains of actinomycetes and new potential antimicrobials.

Awards & achievements

Scientists at JIC are recognised for their contributions to the research community, both nationally and internationally

European Research Council Grants

ERC grants are awarded to researchers based in European research institutions who submit outstanding research proposals. They aim to encourage researchers to stay in Europe, to develop excellent teams and to support their transition to become research leaders.

Dr Diane Saunders, joint Fellow at JIC and the Earlham Institute, received a Starting Grant to investigate the molecular mechanisms driving host adaptation of yellow rust on cereal crops and grasses with the long-term aim of developing new varieties with enhanced resistance to yellow rust.

Professor Daniel Zilberman, who joins the John Innes Centre from the University of California, Berkeley, received a Consolidator Grant for his team's research into how epigenetic information, is passed across generations through modification of DNA, called methylation.

Dr Christine Faulkner also received a Consolidator Grant for her research into how plant cells communicate and co-ordinate their responses to pathogen threats, with the ultimate aim of understanding how defence signals triggered by single cells are transmitted through whole plants.

Professor Caroline Dean

Awarded Royal Society's Darwin Medal

Professor Dame Caroline Dean OBE FRS has been awarded the Royal Society's prestigious Darwin Medal for her work addressing fundamental questions in the perception of temperature cues and how modifications in epigenetic mechanisms play an important role in adaptation.

First created in 1890 in memory of Charles Darwin, the Darwin Medal is awarded every other year for work of acknowledged distinction in the broad area of biology in which Darwin worked, notably in evolution, population biology, organismal biology and biological diversity.

Professor George Lomonossoff

Elected as President of the International Society for Plant Molecular Farming

The ISPMF was established three years ago to promote and support excellence in research, scholarship and practice in plant molecular farming. Professor Lomonossoff was elected the society's second President at a biennial meeting in Ghent, Belgium.

As the society grows in membership and renown it aims to act as a central hub for the molecular farming community and to provide a central resource of information about the latest developments in the field.

Dr Scott Boden

Awarded a University Research Fellowship from the Royal Society

Dr Scott Boden, research fellow at JIC, has been awarded a five-year University Research Fellowship from the Royal Society.

Dr Boden's research aims to improve our understanding of the processes that regulate the architecture of the wheat ear, called the 'inflorescence'. The wheat ears contain numerous flowers that are an essential component in the production of grains. It is hoped that Dr Boden's research will be able to supply breeders with new genetic resources that will increase the number of flowers available for grain production.

The University Research Fellowship scheme aims to provide outstanding early career scientists who have the potential to become leaders in their chosen fields, with the opportunity to build an independent research career. Many former University Research Fellows have gone on to enjoy significant national or international recognition for their work.

Professor Zhihong Xu

We caught up with Professor Zhihong Xu, who worked at the John Innes Institute (the precursor to the John Innes Centre) as a visiting scientist from 1979 to 1980

Professor Xu is a professor of life sciences at Peking University and the Shanghai Institute of Plant Physiology and Ecology (SIPPE), part of the Chinese Academy of Sciences (CAS). He is also currently an academician of CAS, Chairman of UNESCO's Chinese National Committee of Man and the Biosphere and member of the Chinese National Consultative Committee on Education.

How did it feel to be among the first Chinese scientists to work in the UK?
In 1979, following an agreement between the Chinese Academy of Sciences and the Royal Society in the UK, the first group of ten young Chinese scientists came to university labs or research institutes in the UK as visiting scientists. I was the first of this group of young scientists to work at the John Innes Institute. This agreement came at a special time – China was emerging from ten years of the so-called 'Great Cultural Revolution', and the government started to develop a strategy of reformation and openness. We were so eager to discover the new achievements and learn new technologies in our fields of research, and hoped to catch up with the rest of the world's scientific development.

What research did you carry out at JII?
I spent a year in the Department of Applied Genetics, in Dr Norman Sunderland's group. His laboratory had a history of excellent research on androgenesis in cultures of anther and pollen from tobacco, and when I arrived his work was starting to turn towards barley. My research, also on barley, yielded five scientific papers, including identifying components in growth media that are critical for androgenetic development, such as glutamine and inositol, and a factor released into the media from the cultured anthers. It was also found that low temperature affects DNA replication in pollen nuclei. Slow DNA synthesis in cold may be an important factor for pollen to divide rapidly and synchronously and to acquire the potential to develop as a sporophytic structure in subsequent cultures.

What was it like to travel half way across the world to work in a foreign country?
Travelling to the UK to do research was the first time I had left my family, and my first time travelling to a western country. The JII staff helped me to find lodgings with a British family. Every time I return to Norwich, I like to visit them. I always remember how they, and many of my colleagues at JII, helped and supported me in both research and in my daily life. I loved the academic environment, the seminars, the tea breaks, the greenhouses and the garden at JII. I learnt a lot, not only in research work, but also in scientific management, which was helpful when I returned to Shanghai and especially when I later took the job as Director of SIPPE.

How do you feel about the scientific relationship between the UK and China?
Every time I have returned to JIC over the last 20 years I have been very pleased to see so many Chinese PhD students and post-doctoral fellows working there. Many of them have returned to China and become professors in the universities and academic institutes. They play an important role, like a bridge, to promote the collaboration and academic exchanges and friendship. CAS-JIC Centre for Excellence in Plant and Microbial Science (CEPAMS) is a mark of the scientific link and collaboration between the UK and China.
We face a lot of global problems: sustainable agriculture for food production, health and nutrition, biodiversity and environment, all of them are closely tied to plant and microbial science. We must work together, to ensure a bright future for the Earth and the human race.

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The green peach aphid

The green peach aphid (*Myzus persicae*) colonises a wide range of host plants, which is remarkable and unusual among herbivorous insects. Professor Saskia Hogenhout and her team, together with Dr David Swarbreck's group at the Earlham Institute, have sequenced the aphid's genome and uncovered part of the mechanism that allows it to infest so many different plants. This information will increase our understanding of the molecular interactions between the aphid and its host, and also pave the way for improved pest-resistance in crops.

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