University of Nottingham
Future Food

A year in the life of the Future Food Beacon —2018/19

Letter from our Director

The Future Food Beacon is one of six Beacons of Excellence that the University of Nottingham is investing in, in order to respond to a variety of global challenges.

By 2050, there will be an additional 2 billion people on the planet. Currently, 815 million people are chronically undernourished worldwide, while 680 million are obese. Coupled with the challenge of feeding a global population of nearly 10 billion nutritiously, are changes to the climate, rapid urbanisation, and social inequality. This growing global population will need sufficient calories and essential nutrients derived sustainably from innovative food systems. Food decisions are complex, influenced not only by production methods and quality, but also by cultural and historical influences, personal choice, access, and taste.

The Future Food Beacon brings together the power of genome-enabled plant and animal sciences with cutting edge nutritional science, food processing, and manufacturing and digital technologies, informed by an understanding of the economic, legal, social and ethical issues that underpin and shape food systems. We are finding better ways to understand our food systems through transdisciplinary research.

The Future Food Beacon researchers will develop solutions to these challenges, working with practitioners andpolicymakers, across four broad themes: Future proofing agricultural systems; Food for health; Food for sustainable livelihoods; Smart manufacturing for food.

In this first edition of our annual year book, we offer stories from the Future Food Beacon, including interviews with our researchers, stories from our research projects, and experiences of public engagement! Happy reading!

Professor David Salt

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Professor David E. Salt is the Director of the University of Nottingham's multimillion pound Future Food Beacon of Excellence. Prof Salt left the UK after his PhD in 1990 to work as an academic in the US where he became a Full Professor at Purdue University in 2005, and where, from 2004 – 2007, he was the Scientific Director for Genomic Research and Technology for the Bindley Bioscience Centre. In 2011 he came back to the UK as a Chair in Plant Science, and the founder and co-Director of the Centre for Genome-Enabled Biology and Medicine at the University of Aberdeen. In Aug 2016 Prof Salt took up a new Chair in Genome-Enabled Biology at the University of Nottingham.

Tell me about your career, how did things begin and evolve?
I've been working on this science for a long time. I've always been interested in how plants adapt to their environments. I did my undergraduate degree in Biochemistry but then I did a Masters in Computer Science, because I decided computers were going to be important (this was the early 1980s). I was really interested in modelling. Because I'd had government funding to support my Masters, I was not eligible for further government funding for a PhD, so I was limited to PhDs that were funded through other mechanisms. There was a PhD at the University of Liverpool, funded by The Royal Society, working on copper tolerance in *Mimulus guttatus*, the yellow monkey flower. At the time, I was in Sheffield doing my Masters, I was into clubbing and the scene in Liverpool was fantastic so I ended up there doing a PhD. After my PhD, I decided I wanted to go to London so I did a postdoc at University College in biochemical engineering. I was studying the large-scale purification of proteins. It was completely different to what I had done my PhD on, but it was interesting and a fun place to be. This is when I discovered the 'world music' nightclub at Ronnie Scott's Jazz Club just down the road from my favourite coffee shop in London 'Bar Italia' in Soho.

Once that postdoc was finished, I was keen to work abroad. After some investigating I found several key people

working in the area of metals in plants that were based in the US. I wrote to a few of them, asking if I could join their labs as a postdoc. I wrote to George Wagner, who was based at the University of Lexington, in Kentucky, and he had funding for a two-year post so I packed up everything, took my small suitcase and guitar, and left for Kentucky. I can still remember getting off the plane for the first time – the temperature, the cicadas, the humidity. It was a new world.

I worked on how cadmium is transported across plant membranes, and made some seminal discoveries during that postdoc. I published a paper in the Journal of Biological Chemistry (JBC) that has led to a lot of molecular work since then. I met my wife, Karen there too. After two years, I still didn't want to come back to the UK, and so I wrote to Wilfred Rauser, who I knew through the literature, who was at the University of Guelph in Canada. He had done a lot of work on compounds called phytochelatins, which I was involved in discovering during my PhD, and which are involved in binding metals in plants, as part of the detoxification mechanism. We knew from work that George Wagner had done while I was in his lab that the peptides that bind the metals seem to accumulate in the vacuole in plant cells. We did not know how the peptides got into the vacuoles, so I proposed to go to Wilfred Rauser's lab to study that transport process. We were in Guelph for two years. Our twin boys were born there. Once that postdoc was finished, I decided it was time to move on from being a postdoc and I was lucky enough to get a position at the University of Rutgers, as a Research Assistant Professor. That was a five-year, fixed term position. I was at Assistant Prof level, but I just did research. I was able to get my first two big grants while I was at Rutgers, initially from the USDA, and then the US Department of Energy – I have been continuously funded ever since. One grant was to continue work on the transport of phytochelatins, and the other was to work on a project examining a small molecule that binds nickel in special plants that hyper accumulate metals such as nickel and zinc. I published papers on that research, and had my first postdoc there, Ute Kramer, who has gone on to be a successful scientist. Since that first post I have had 29 postdocs in my lab, many of whom now have their own labs in the US, China and Japan, or are working in industry. Being at Rutgers was an interesting experience. I learnt how to run my own lab, write my own grants, figure out what it means to be an independent scientist.

Because that was a fixed-term position, I then began to look for a tenure-track post. I was lucky enough to get a position at the University of Arizona in Flagstaff. That was my first experience trying to run a group and teach. I was based in the Chemistry department, as an Assistant Professor of Chemistry. That was quite interesting because my first teaching assignment was to teach intro chemistry to freshmen (first years) and I hadn't done Chemistry since my A-levels! I also taught two levels of biochemistry. That was tough. I was teaching full-time, writing grants, trying to keep my lab going. I met Mary Lou Guerinot, who became a long-term mentor, who is based at Dartmouth College in New Hampshire, US. We wrote a grant together with Julian Schroder, Jeff Harper and John Ward for the US National Science Foundation (NSF). They have a programme called the Plant Genome Programme. We put together a project on ionomics in 2000. We were successful on our second attempt and the grant was worth around $8million. I got tenure at Flagstaff. I then applied for a position at Purdue University. They had an opening for an Associate Professor and I was able to get a permanent position at Purdue. We moved to Indiana in 1999/2000, and that is where we had our daughter. I was at Purdue for 11 years. I started to build my lab and my reputation. I won more grants from the NSF. I branched into natural variation and looking at the molecular mechanisms that underpin natural variation in the ionome. In some sense, that was me getting back to my PhD work. I was able to get funding from the US National Institute for Health (NIH), which was quite unusual because they only rarely fund plant people. That grant allowed me to grow my research area in natural variation. I got great postdocs, including Ivan Baxter who leads his own group now at the Donald Danforth Centre, St Louis, and Daiyin Chao, we published a paper in Science and he is a now a Professor at the Shanghai Institute of Plant Physiology and Ecology.

By 2010, Karen had finished her PhD and was looking for her next step. She was offered an Assistant Professor's position at Purdue but we felt that for Karen's career it would be better if she went somewhere else. It is never really a good idea to stay at the same institution. After 20 years in the US, I decided I wanted to come back to the UK. I can't explain why exactly. My two boys were at university at that point, and one was back in the UK already, and our daughter was in high school. In 2008 I had been over at a meeting in Aberdeen, on arsenic accumulation in rice. I thought it was an amazing city. When we started to think about coming back to the UK, we were dealing with what is called the 'twin body' problem - you have two academics and you are looking for a university that will give you both positions - so that narrowed things down a little. I wanted to build the Centre for Genome Enabled Biology, an idea I had been developing for a while. I wanted to do something bigger than just my own science. I wanted to take hold of this emerging field where people are using genomics and the associated methodologies to ask questions across disciplines. I thought we needed to create a platform to allow us to do genome enabled biology and that would allow us to be leaders in many different areas. We moved to the University of Aberdeen and we were there for five years. I was able to establish the Centre for Genome Enabled Biology & Medicine at Aberdeen, and it is still there going strong. After five years at Aberdeen opportunities came up at UoN so we decided to move to Nottingham. Karen started in May and I started in August 2016.

Tell me about the origins of the Future Food Beacon?
I am still really interested in genome enabled biology - the bioinformatics, the sequencing, the phenomics, everything together in a pipeline. Prof Malcolm Bennett is also interested in this concept. We initially put in a Beacon around that concept, called genome to phenome. It was about trying to understand the connections between the genome and the organism, how the genome is translated into the organism. We justified the project ideas through the concept of food security but it was more about the fundamental science behind getting new crops, and eventually using the same platform for livestock. At the same time, Prof Tim Foster was putting in a Beacon bid strongly focused on the food side.. We submitted separately and as part of the review process, the reviewers suggested that we fuse the two ideas. I talked to Tim about bringing the two projects together, and I was really eager to lead the Beacon, which fortunately Tim was okay with. I am now totally becoming immersed in the whole food side of things. Once I started to think about how I wanted the Beacon to work, I realised I wanted it to be an open platform for research. I realised that we needed to be enabling research across the whole food system, including Social Science and Arts and Humanities.

What are the aims for the Future Food Beacon?
I think there are two arms to this really. There are the rigid deliverables that the Beacon has. The University is investing £16 million in the Beacon, and they want to recoup that so they are expecting the investment will raise success in terms of getting external grant funding. It'll raise our ability to publish higher quality papers and it will increase our international standing. People will look at UoN and think wow, they're doing amazing work in this area - they're publishing all these papers, giving great talks, producing great students and postdocs. We have very clear targets that you can put a number on. Outside of that, I am also hoping that we can really have an impact on the food system in terms of food security, nutritional security. It is a massive and daunting problem. In terms of grants success and getting external funding, a lot of that is about telling a convincing story. Refining the narrative is the first thing you need to do and then you can start to use the narrative in different places to generate funding, interest and buy-in to the project. To develop a good narrative about something you need to identify a topic for your story. If you can do that, that gives you a nice place you can have significant impacts. Those stories can be different. The stories that we are building around food deserts is one such example. It is an intriguing term, there is good content, it is easy to engage people. But it is also a space where we can have an impact. We also have a cocoa project with this potential. Once you start affecting people's lives, it becomes a talking point.

Another outcome which is perhaps subtler is this idea of it being a disruptive mechanism. The University knows it wants to improve but it is an incredibly complex institution. To make anything happen at the university, on the systems level, is almost impossible. It is easy to make things happen at an individual level, because it is fairly chaotic. If you have resources to invest in something, and you give the money to existing mechanisms, what is most likely to happen is more of what is already happening. It isn't necessarily going to change anything. The Beacons are, in a positive sense, disruptive. They sit outside the traditional systems - these are not bounded by a single school or faculty, but rather they intersect multiple organisational units. They can influence people. Stuff is going to happen. Through that disruption, we may be able to make some permanent change for the better.

What is the importance of the Beacon for ordinary people?
Cocoa is a clear example of research impacting ordinary people. We have just got back from Colombia. While we were there we worked with female smallholder cocoa growers, trying to help them improve the quality of the beans and enabling them to sell their cocoa beans to premium chocolate makers in Nottingham. They get more for their beans, and this in turn helps improve their families' livelihoods. So, there is a direct impact. Stories like that have a lot of content, a good narrative, and they impact directly on a person. We are always looking for stories like that. There are other projects that are maybe more inspirational, so people can look to see what we are doing and become inspired. We need to learn how to communicate that. We have a project in Senegal on pearl millet that is focused on capacity building to improve both the crop and its uses, so that people in Senegal directly benefit. We are also very focused on community outreach and engagement. That will have a big influence individually. Plus we are working with small businesses, working together to help improve various companies, and that will impact on people too. There is a balance to be struck between good science, supporting businesses, and connecting with people.

Do you have any advice for young scientists?
You need to figure out what your story is. It sounds simple, but what is your story? When you start out, you're thinking about an experiment, always. And you need to end up thinking about a programme. In order to sell your programme, you have to be able to wrap a narrative around it. It becomes what is unique about you. You have to have enough focus so you can put in targeted grants but it has to be flexible enough to allow you to play in a broad space. For example, I work on ionomics, so I can publish papers on complicated genome-wide association mapping in Arabidopsis, looking at arsenic accumulation in rice… I can work on cadmium accumulation in cocoa and get funding from Mars. It is all the same story. I can sell that story to all those different people because I have a unifying narrative. Getting that is really important. You also need to figure out what problem you are going to study and that problem needs to have societal significance.

Do you have a greatest career moment?
It is a series of events. When I decided I was going to move from the US, I was really interested in taking a sabbatical. You get a sabbatical every seven years in the US, and I hadn't had one, and so I was long overdue. I had met Luca Maroni, who was a head winemaker in a vineyard in Italy and I wanted to do my sabbatical there so I came up with this crazy idea to do ionomics on grapes, while I was working in the vineyard for three months, over the harvest period. While I was doing that project, I was awarded one of the highest research awards at Purdue - the McCoy Award. I went back to the US to give my acceptance address and as part of my talk, I spoke about my research in the vineyard and how I was looking at the effects of the terroir on the ionomics of the grapes. The President of the university thought it was fantastic. It summed up for me the scientist's life. You can be doing the coolest stuff, on all kinds of levels, but you need to be bold! That is one high point but there have been many!

Murray Lark is Professor of Environmetrics and a member of the Future Food Beacon. Prof Lark is interested in spatial statistical models and their application to problems in sampling and experimental design and the analysis of data from large surveys. Much of his work is concerned with understanding constraints on crop performance with respect to soil water and nutrients. He is leading a UKRI GCRF project working in Zimbabwe, Zambia and Malawi on conservation agriculture. This project is focused on building research capacity and partnerships in these countries, so that an integrated assessment can be made of options for “climate smart” agriculture and the impact of different strategies on food and water security. Prof Lark is interested in the way messages about uncertainty are framed, and how research findings are communicated to different stakeholders. Prior to joining UoN, Prof Lark was at the British Geological Survey.

Professor Murray Lark

Can you tell me a little bit about your research and career?
I joined the University of Nottingham in December 2017. Prior to that I was at the British Geological Survey. Before BGS I was at Rothamsted Research where I led the Environmetrics research group in the Biomathematics Department. My particular area of interest is in spatial statistical methods for soil science, sometimes called pedometrics. I enjoy developing mathematical models of spatial variation which capture features of how real soil varies. I am interested in the variation of the soil itself, the processes in the landscape which give rise to it, but a quantitative understanding of this variation at different spatial scales is also essential for practical purposes if we are to obtain robust information about soil and crop

systems. I am therefore interested in how statistical models can be used to design efficient experiments or sample plans, and then provide useful information. This information might take the form of a map, or an equation to predict a property of the soil.

My focus now is on understanding constraints on crop performance with respect to soil water and soil nutrients. I am working with colleagues from the UK and Africa in several connected projects concerned with nutrient status of crops and how these are controlled by soil factors at the landscape scale. I am also working on conservation agriculture which is a set of strategies aimed at making agriculture more resilient in a changing climate. Within the UK I am working on methods to extract information from large data sets collected on-farm, and am examining how sensors can be deployed to provide farmers with real-time information.

How did you become interested in your area?
I was always interested in the physical environment. In the part of Africa where I grew up the landscape is ancient. Some of the erosional land surfaces began to form when Africa was still part of the Gondwana supercontinent. Crossing the Zambezi valley is like time-travel, and as you encounter erosion surfaces of different age, at contrasting elevation, so the climate, soil and vegetation change. I was intrigued by the soil, and how soil under contrasting tree cover differed in its properties. However, my main interest when I was a youngster was in elephants. One of the problems with managing elephants is the destructive effect they have on trees. When I was about 10 years old I decided that it was necessary to measure the rate at which the tree canopy was being lost to elephant browsing in parts of Zimbabwe. No one could tell me what the rate was, so I decided to find out myself. The rate of tree loss is not obviously an easy thing to measure. I decided to approach the problem using aerial photographs. I obtained repeat photographs of the same area, with a large elephant density. My plan was to count the trees on each and so estimate the rate of loss. But of course, as soon as I looked at the photographs, I realised that counting all the trees was an impossible task. So I had to think about sampling, how you can make estimates of quantities that you can't measure exhaustively by appropriate sampling design. That is when I began to get interested in a mathematical framework to address the problems of obtaining environmental information, which is what environmetrics is all about.

I developed an interest in mathematical biology, and so I applied to Oxford, intending to study Zoology. Early in the first year I went to some introductory lectures on the physical environment for biological scientists, given by a soil scientist at the university. He talked about the soils and landscapes of the Zambezi valley. It did not take long for me to set zoology aside, and I took a degree in Pure and Applied Biology which allowed me to spend a lot of time studying soil science, and also statistics. In my D.Phil research I looked at the spatial variation of remote sensor data, and multivariate methods to analyse them. I then held a University of Wales fellowship where I applied some of these ideas in arid environments of southern Spain. When the fellowship ended an opportunity arose at the BBSRC's Silsoe Research Institute where they were interested in precision agriculture. The idea of precision agriculture is to understand the spatial variation of soil–crop systems at within field scale, and to adjust inputs in response to this variation, rather than treating soils as uniform. After the move to Rothamsted, I continued looking at national scale soil monitoring options, from a statistical design point of view. Then I moved to BGS where there was still a lot of interest in soil science in relation to agriculture but then a range of other topics as well. I became involved with some of the work that was being done in Southern Africa on micronutrients in soil and crop. That was the first area where I was collaborating with people at the university here, as well as colleagues at BGS.

Tell me about your current project in Southern Africa?
I lead a project called CEPHaS (UKRI GCRF funding) on conservation agriculture in Zambia, Zimbabwe and Malawi. CEPHaS looks at strategies for crop management in an increasingly erratic climate. Conservation agriculture (CA) is a set of what are called "climate smart" strategies to make agriculture more robust. It entails the avoidance of cultivations to maintain soil structure, the use of mulches to protect the soil and enhance its organic status, and crop rotation to manage pests and diseases.

It has been recognised that we know very little about what changes happen in the soil under CA, particularly as so far it affects the dynamics of water in the soil. One area which has not been considered at all is the implications of these practices for the recharge of ground water. Ground water is sometimes undervalued as a resource in Africa. But boreholes or shallow wells are very important for many communities. No one really knows what the effects of uptake of conservation agriculture would be on groundwater. Does the physical improvement in the soil mean you will get greater infiltration and therefore improved recharge? Or does improved retention of water in the top-soil, which may then be lost by the crop's evapotranspiration, mean that you will see reduced recharge? Our objective is to build the capacity of a collaborative network in sub-Saharan Africa, along with UK partners, which is able to evaluate how CA practices affect the behaviour of water in the soil and so the resilience of cropping systems and their impact on groundwater supplies. Core to this are the interdisciplinary links we are creating between soil physicists on one hand and hydrogeologists on the other, and geophysicists. And statistics provides the glue to hold it all together, of course!

Is your research easily applicable in ordinary settings?
That is a very important question. The current agenda for the Global Challenges Research Fund in the UK should be making us think much harder about it than we have before. It is very easy to say "we are looking at how certain agricultural practices affect the soil, and its behaviour, so it should be very obvious that there are potential benefits for agriculture and the agricultural sector" but of course that doesn't just happen. It is partly

the responsibility of scientists to engage with partners to make sure that that impact is realised.

Because of this we are engaging with a range of stakeholders in the CEPHaS project. During the project network meeting in July this year in Malawi we met representatives from the land resources and water resources departments of the Ministry of Agriculture, Irrigation and Water Development. We also met representatives of international donors, local NGOs and government researchers. This enabled the project team as a whole to develop our scientific ideas in the context of what policy makers, extension workers and NGOs are seeing on the ground.

One particular theme that bears both on science and its impact, and one in which I have taken a direct interest, is the effective communication of scientific findings which have an element of uncertainty. My work is about statistical inference from data. This is concerned with the variability which arises from the complexity of processes in the natural world, and the uncertainty which is therefore attached to any experimental finding or estimate from a survey. It is not easy to communicate this to a general audience, particularly when the most natural way to express uncertainty is in terms of probabilities. I have often run into this difficulty when planning or explaining research to wider stakeholder groups such as farmers or policy makers. Key to the more general question about how we ensure impact of our research is how we frame the ways to communicate it. You can't just leave that to chance. You need to be aware of how people handle numerical information, the heuristics they use to try and interpret it and make decisions with it. I have been fortunate to have the opportunity to collaborate with psychologists on these questions. They are by no means settled, and there are many interesting problems to be tackled which are essential to effective communication of science.

How does being here at UoN within Future Food help you achieve your goals?
There are many opportunities, and these arise from the scope for interdisciplinary collaboration. Before starting at the University I had collaborations in soil geochemistry, soil-root interactions and the effects of zero-tillage on greenhouse gas emissions from the soil. Within the Future Food Beacon I hope to be able to widen that collaboration to look at food and agricultural systems more broadly. Agricultural systems are set in the spatially variable landscape, and that means that their management and optimization requires quantitative insight into the scale-dependent variation of the environment. That is how we might reduce costs and environmental impact of farming by spatially variable application of inputs, for example. In the past the study of agricultural systems in the field and the study of plants or animals at the molecular scale have been seen as mutually exclusive activities, competing for limited resources. But neither approach can deliver on its own, and I would suggest that quantitative methods to examine processes at multiple spatial scales are key to the necessary integration. I would also like to develop links with the social sciences. Most smallholder farmers manage small patches of land in complex ways, often based on sophisticated ecological understanding. It would be very interesting to understand better how such farmers perceive their environment and integrate information from different scales, and I would wager that spatial statistics could help with that.

Do you have a greatest career moment?
A career in applied science offers varied kinds of job satisfaction. For example, I work with statistical models which we develop to capture aspects of how the world works in ways which are practically tractable. It is always gratifying when you see that a mathematical abstraction for describing something as complicated as the variability of the soil, has actually worked because the numbers drop out as you predicted. We can use numbers to make sense of the complexity of the world, that is always deeply satisfying to see. On the other hand, just the other week in Malawi I saw a geophysical array being set up on a long-term conservation agriculture experiment as part of the CEPHaS project. This experiment has been running for the last twelve years or so, and it has produced all sorts of interesting information about the system, but this bit of extra kit that we're getting in the ground is going to open up a whole new perspective on aspects of water and soil under conservation agriculture that we've had no clue about before. That is hugely exciting.

Do you have any advice for others?
I've never really tried to organise my career. I'm not a great one for five year plans, I'm a bit sceptical about those. So that is my first bit of advice, not to get too worked up trying to do horizon scanning. My approach is different. I've always had an internal agenda of questions that I want to answer about the mathematics of the soil system, and then I try to stay alert for reasons why someone should pay me to tackle them because some important problem hangs on them.

For example, one 'left-over' question on my internal list after my doctoral research was about how to estimate certain parameters of a statistical model for soil when the data are particularly messy. I needed a way to decide which estimator was best when two or more disagreed. That sounds dry as dust to the non-statistician but I did not have to wait to long for an opportunity to pursue it with funding from the then Ministry of Agriculture, Fisheries and Food. They wanted to know how to make sensible decisions about monitoring contaminated soil. I was able to hang my scientific interests on their practical agenda. I think that is half the fun of being an applied scientist, being able to spot the opportunities to do something which you think is interesting from the scientific point of view, but which will also have impact. One question near the top of my personal list at the moment is whether there are any laws we can spot empirically or infer from theory about how the variation of soil is structured over scales from pore to continent. Does variation grow smoothly as we consider increasing scales, or are there scales where it goes up in jumps? Again, I would wager that there are some "real-world" problems out there on which one could hang that question!

Associate Professor Levi Yant

Levi Yant is an Associate Professor in Life Sciences and a member of the Future Food Beacon of Excellence. His research is focused on wild plant populations to understand how evolution finds solutions to significant environment and physiological challenges. Dr Yant uses innovative population genomic approaches to identify changes specific to adapted populations. This reveals candidate genes and process mediating adaption. Dr Yant completed his PhD at the Max Planck Institute for Developmental Biology, pioneering the application of genome-scale technologies to plants, in order to understand the molecular control of flowering time. While a postdoc at Harvard, Dr Yant focused on evolution and population genomics to understand the molecular basis of adaption.

What do you do?
I use genomics to study the evolution of plant and animal populations to understand how they overcome environmental hazards. By working on quantifiable adaptations, we can understand the ways replicate populations adapt and determine if there are common factors; if, in fact, evolution can be predictable. Many of these systems can also have clear impacts on the rational design of future plants, for example.

How did you get into this kind of work?
I've always studied evolution. I started in HIV vaccine development and that was really exciting, because we were able to use quick and highly reductionist systems to track viral evolution inside infected hosts. It was important work, but a rather difficult thing to do in the long term – a very territorial field – so I was drawn to Arabidopsis because it is also quite fast and offers many interesting questions, especially the wild outcrossing relatives of *Arabidopsis thaliana*. It is one of the fastest plant systems where we can see evolution happening almost in real time. That is how I got into plants, but it has always been evolutionary genetics.

Can you tell me a little bit about your history?
I started university in Wisconsin. I began graduate school studying HIV virus evolution, switching systems halfway through my PhD to Arabidopsis, at the Max Planck Institute for Developmental Biology in Tübingen, Germany. I finished my PhD there and then I did a postdoc at Harvard, working on the evolution of development (Evo-Devo) in non-model systems with Professor Elena Kramer, who was a fabulous mentor. I then came over to the UK to join the John Innes Centre, thanks in part of an ERC Starting Grant from the European Union.

What is your aim while you are with the Future Food Beacon?
I want to develop meaningful collaborations between the Beacon and both East African and Chinese partners with the goal of making new impactful and interesting work possible on underutilised systems. This is in addition to growing my research programme working on the adaptation of natural systems to environmental stressors, as well as genome evolution. In other words, I'd like to do a lot while I am with the Beacon!

One way I like to think about scientists follows what has been written about other thinkers: there are hedgehogs and there are foxes. Hedgehogs know one great thing, and they obsess on that thing. They focus on that one thing with laser intensity. On the other hand, there are foxes: they love to do many things, get involved in different problems, and collaborate a lot, working on diverse systems. One can be a bit fox and a bit hedgehog, but I see myself pretty solidly in the fox camp. My science has always been highly collaborative, and I've always worked on multiple systems, both in terms of the biological context, and species. When the Future Food Beacon opportunity came up, I thought that was an even more powerful way to use my natural traits better, to collaborate broadly, to work on diverse systems. I'd like for it to be relevant to food security but also for us to have a strong fundamental science focus.

How do you think you balance that?
It's crucial to pick the right study systems to have the best shot at both important fundamental science and applied impact of the science. On the one hand many amazing people have been working on the major systems, for example, wheat and maize; so I want to contribute to new systems instead, where possible. I'd particularly like to focus on underutilised, 'orphan' crops. I know there are a number of people at Nottingham who are also interested in that, and that was an attraction as well, developing links in Asia and East Africa with groups that want to do excellent science on indigenous crops. It will be an adventure to see where we can take this!

"We are bridging the gap between interesting, fundamental science and increasingly urgent practical issues."

Was it that diversity and collaborative opportunities of the Beacon that attracted you to the post?
Yes, definitely. And the strong, progressive, forward-thinking leadership was a real attraction. The people at the Beacon are very good at identifying where new opportunities are, and have links all over the world which is hugely important.

How do you explain your research to an ordinary person?
We try to understand how evolution works, at a fundamental level. We are happy to work on different, diverse, and strange adaptations that we find in the wild. By looking at repeated evolution in different organisms to the same stressors, this gives some fundamental idea of whether evolution is constrained, whether the same changes happen each time or whether evolution can meander down different paths. The beautiful side benefit of that is you can learn a lot of different and useful biology doing that.

How did you first become interested and involved in science research?
I was really interested in some pretty far out science fiction and what people are trying in terms of life extension while I was in college. I thought that was really progressive and forward thinking – different ways to extend life spans (and, crucially, extension of health and high-quality life span) in different organisms. So, when I finished my undergraduate degree I called up a scientist on the other side of the country doing that work, who had just had a fancy paper in Science - I think it was one of the first microarray studies in a vertebrate - looking at the global gene expression impact of caloric restriction. I offered to work in his lab, to experience what 'doing science' was like, because I did not have that experience as an undergraduate. I was a technician in his lab for a few years and I learned I really liked it. Oddly, though, I am not a bench scientist at all now, but that was a natural development towards computational work for which I am better suited and excites me more.

Do you have a greatest career moment?
Hmm… I just had one that felt pretty special that I'm riding high on: a few days ago we had a paper really well reviewed at a top journal. It's not just that it was well-received, it's how it came about: the thing that made me most excited about it is that the paper is an equal partnership of three shared first authors which is a bit uncommon, even in genomics. And they all absolutely poured themselves into it, with absolutely no territorialism: they worked so well as a team that as senior author I really felt I was just watching the beautiful process unfold as they put together something somewhat special. They drafted and redrafted it all together over the course of six months in an intense way. It is a very carefully honed manuscript and by the time I got it, needed very little input; it was deep and beautiful. The paper is really important for the three first authors, and it was a really great moment for me, as a lab leader. As a young group leader it is very difficult to know how much to micromanage. I am still learning that, progressing in that skill, and this was a happy example for me of how things can work very well with a light touch.

Do you have any advice for young scientists?
Yes! Please do not worry too much about things! That sounds horrible from someone who has a long-term job he loves now, but earlier in my career I worried all the time and it only made me less productive. And of course, it is a miserable way to live. Just do you best and push at what captures your passion, and be selfish to that. If you love it, keep doing it, and work hard. But also play hard! Do intense non-science activities that absolutely reset and refresh. For me, that's trail running, sailing and rock climbing. I am pretty mardy and miserable if I miss out on any of these for a few days, even when the science is going really well.

Will your research impact on ordinary people's lives?
We are bridging the gap between interesting fundamental science and increasingly urgent practical issues such as environmental degradation and climate change. In particular, recent studies published by my group have increasingly focused on how certain amazing plant populations have evolved to thrive on highly degraded, saline, or heavy metal-contaminated soils. This work contributes to a knowledge-base that we can use to design crops resilient to climate volatility and environmental hazards. Complementary to this, we are starting to work on dramatically understudied orphan crops that constitute key components of people's diets and livelihoods in developing nations. This work can have a rapid impact on ordinary people as we characterise and develop crops readily adapted to highly challenging local conditions. Going forward, I am optimistic that this work can aid both developed and developing nations as we struggle to cope together with climate change.

Dr Michael Pound

Dr Sina Fischer

Meet the Future Food research fellows

Dr Rahul Bhosale

Dr Sally Eldeghaidy

Dr Gabriel Castrillo

Dr Guillermina Mendiondo

Interviews with our researchers

We are very excited to introduce Dr Rahul Bhosale. Rahul is a BBSRC Discovery Fellow and a Nottingham Research Fellow in Phenomics and Functional Genomics. Rahul uses functional genomic approaches to dissect molecular mechanisms underlying anatomical traits that mediate stress resilience in crops. His research seeks to understand plant traits and adaptive responses that influence nutrient and water foraging. Prior to becoming an NRF, Rahul was a Newton International Fellow at the University of Nottingham, and completed his PhD at The University of Ghent. He was named on the Forbes 30 under 30 Europe list in Science & Healthcare 2017.

Dr Rahul Bhosale

What is the focus of your research?
Nearly 800 million people suffer from hunger every day and this problem is going to intensify over time due to increasing population pressure, loss in crop yield due to changing climatic conditions and reduction in farmland due to urbanisation. The challenge is to double our crop production within the next decades without expanding agriculture to new farmland. To achieve this, we need to develop or identify new varieties that use soil resources, such as nutrients and water, efficiently. Root architecture (the length and breadth of a root system in the soil) and anatomy (the arrangement of tissues and cells within) critically influences water and nutrient uptake efficiency and therefore can lead to higher crop yield under water and nutrient stress.

My research mainly focuses on root anatomical traits such as aerenchyma (i.e. air-space) formation that enables plants to acquire more soil resources for less metabolic investment and thus improves yield under drought and sub-optimal nutrient conditions. Recent advances in high-throughput root cross-sectioning using Laser Ablation Tomography and imaging techniques, collectively termed the 'Anatomics' approach, now allows us to study root anatomical traits in a large number of varieties or a population of crops. I am combining this anatomics approach with functional genomics techniques such as Genome Wide Association Studies (GWAS), CRISPR-gene editing and Single Cell and bulk RNA sequencing to understand molecular mechanisms underlying aerenchyma formation in maize. I am also using molecular assisted breeding approaches to translate such knowledge into other under invested crops such as pearl millet. In the long-term, I plan to expand this novel approach to study other anatomical traits in maize as well as other crops.

In parallel, I am using my multi-disciplinary expertise (in bioinformatics, mathematical modelling, and molecular and cell biology) to actively participate in several national and international collaborative projects for determining spatio-temporal gene regulatory networks underlying plant developmental processes such as endoreplication, root-hair and lateral root development, root penetration and root tropic responses as gravitropism and hydrotropism.

What brought you to Nottingham and the Future Food Beacon?
I worked with Prof. Malcolm Bennett here at the Sutton Bonington Campus of the University of Nottingham from 2015-2018, initially as a Newton International Fellow and then as a research fellow on a Royal Society Global Challenge Research Fund grant. I really enjoy working on this campus as it has experts from multiple disciplines, making it a vibrant and stimulating research environment. It is also equipped with all the infrastructure required for my research. With the Future Food Beacon, the campus is becoming more fascinating as new researchers are joining and new infrastructure is being developed. Everyone is collectively working towards the bigger goal of addressing the global food security problem. Such initiatives naturally generate more opportunities for collaborations and increases synergies among researchers. That is why I wanted to be a Future Food Beacon team member.

What does a typical day look like?
My typical day is usually packed with multiple activities, where I manage my time to work on my own research project, supervise students, tend to academic responsibilities, and discuss ongoing research and new ideas with other researchers.

Do you ever think about how your research affects ordinary people?
I come from an agricultural background and grew up on a farm. I always therefore think about translating the fundamental knowledge learned from my research – using breeding or genetic improvement programmes towards developing stress tolerant and yield improving varieties – that will directly benefit farmers. One of the aims of my project is to translate knowledge learned from maize to other 'orphan crops' such as pearl millet, which is a staple crop in Africa and South East Asia, where hunger is a major concern.

How did you get involved with work in Senegal?
I am collaborating with researchers at Nottingham as well as Prof. Laurent Laplaze, IRD France, and Dr Ndjido Kane, Institut Senegal de Recherches Agricoles to work on pearl millet. I tapped into this network and will be working with them for one of the aims of my research project during the fellowship.

Do you have a greatest career moment?
I am very excited to be the recipient of a BBSRC Discovery Fellowship. I will be taking this up in 2019. In 2017, my research was recognised by Forbes and I was selected as an exceptional talent under the age of 30. I was honoured on the Forbes 30 under 30 list in the Science and Healthcare Category in Europe.

What advice do you have for young scientists?
My background is multidisciplinary and that helped me in my previous stages of career. I would advise young scientists to widen their skill set and expertise in computational as well as experimental techniques.

"I was honoured on the Forbes 30 under 30 list in the Science and Healthcare Category in Europe."

How does Future Food help you achieve your goals?
My immediate goal is to successfully transition from an independent researcher to a group leader. The Future Food Beacon fellowship will allow me to apply for funding to build my team. The Future Food Beacon initiative supports a wide range of research projects with local as well as global partners. Thus, the Future Food Beacon will not only allow me to foster my current network of collaborators but also expand it further to answer important questions and challenges in my research.

Where do you get inspiration from?
My inspiration for becoming a scientist is related to my experience growing up on a farm in India. We had three seasons of dry weather, rain and winter. It amazed me how the different weather and temperature cycles affected plant growth and development. That sparked my curiosity to become a scientist. Now, I get my inspiration from my wife. She is a structural biologist, working on global health issues.

Is there anything you are looking forward to?
In my previous research, I have been using bulk RNA sequencing to determine molecular mechanisms underlying developmental processes at organ and tissue scale. In this project, I am really looking forward to using Single Cell RNAseq technique to determine mechanisms regulated at cellular scale. This will help me significantly broaden my skill set. Additionally, I am very excited about working directly with farmers and breeders in Africa during this project.

Dr Gabriel Castrillo

Gabriel Castrillo is a Nottingham Research Fellow in Plant Microbiome. 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.

Tell me about your research?
My work is mainly focused on the study of how plants and microbes interact. I am interested in doing that in the context of nutrition. I want 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.

How did you get involved in this research?
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 signalling 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.

How does being at UoN and being part of Future Food help you achieve your goals?
It is exciting because you get to interact with so many people from different disciplines. The level of excellence is very high, so the environment, my mentors, pushes me to achieve new levels of excellence. There is a culture of collaboration, of finding novel and exciting topics for proposals and grant applications, generating preliminary data, talking to visitors. The science here is very dynamic and very good so it is a challenging environment to work in.

How does your research affect ordinary people?
At the moment I am working in fundamental Biology so I want to answer fundamental questions. I want to understand the system, answer theoretical questions. But these theoretical questions can be translated to crop systems. At that point, they will impact on ordinary people. These fundamental questions are essentially related to plant nutrition and food. It is important. It is the basis for the future of crops and agriculture. Specifically, I find the microbiome field very exciting. There is a lot of potential. It is growing incredibly fast but it is still in its infancy so we need to answer a lot of fundamental questions in order to understand the system.

How do you explain your research to ordinary people?
All living organisms, including humans, are colonized by, and cohabit with, microbes. My work is trying to understand how the microbes that live together with the plant impact or affect the development of the plant. How do the microbes that live in the root and in the leaf affect the accumulation of nutrients? How important are the microbes for nutrient accumulation? How do microbes help the plant to cope with nutrient deficiency? How do microbes change the morphology of the root and leaf in order to make the plants better?

Where do you get your inspiration from?
I push myself a lot. I want to be competitive all the time. I want to be a reference in the field. I know that there are a lot of people working in defence and microbiome, but I don't know so many people working in nutrition and microbiome, so I want to explore this field. I want to build a lab, I want to generate knowledge, and I want to be a reference in this field.

What is your greatest career moment so far?
I have two essentially. The first was when I finished my PhD. I think the PhD is an important moment for all scientists, there is before and then after the PhD. My second moment was when I published my Nature paper. That was something I really wanted to do. I dreamt about that moment for so many years. I worked really hard for that so to finally accomplish that was amazing.

Is there anything you're looking forward to doing in the near future?
I am the type of person who has very clear objectives and I work year by year. I have two objectives. One is to publish my work in a high-impact journal. The second is to obtain a permanent position. There are many things you need to accomplish to get that – a lot of proposals, PhD students, postdocs. All of the things are linked.

What does a typical day look like?
My days are super busy. Being busy is not always a good thing, you need to time to stop and think about what I am doing, the goals I want to achieve, read papers related to what I am doing. I have lab responsibilities and work, I am writing grant applications, attending meetings. It is very busy!

What advice do you have for young scientists?
Science is not about intelligence. It is about discipline. It is having the courage and the strength to repeat, and repeat, and repeat, and try again and again, and push and push. At a certain level, everyone is the same. Everyone is very intelligent. What makes the difference is the discipline. To work and work and work, try again and again. That is what differentiates one scientist from another. Successful people are really hard workers, obsessive. You also need to be intelligent of course, but also very creative. But you must have discipline.

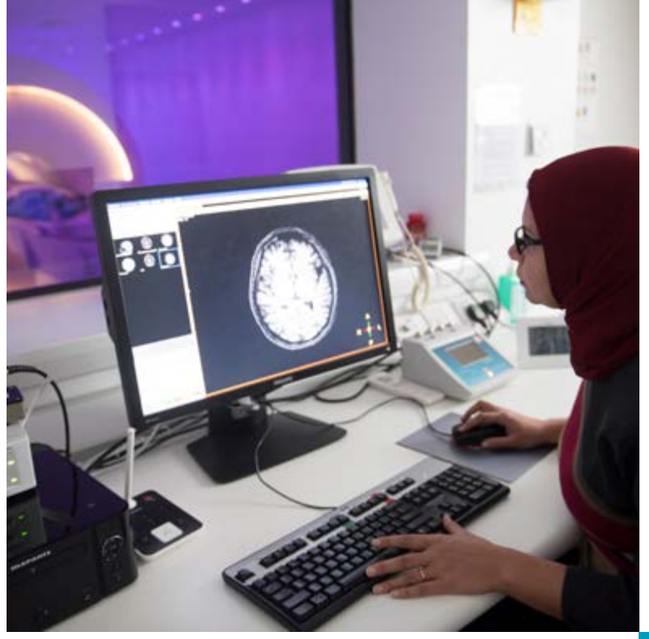
Sally Eldeghaidy is an Anne Mclaren Research Fellow in Sensory Science. Sally uses functional magnetic resonance imaging (MRI) to understand neural mechanisms involved in food intake, food choice and consumption. She focuses on understanding the sensory-brain-gut interactions in the regulation of food intake to tackle obesity, and the effect of taste phenotype and genotype on taste and flavour perception. Previously, Sally was a Research Fellow in the School of Physics at the University of Nottingham.

Dr Sally Eldeghaidy

Tell us about yourself and your research?
I am an MR physicist. I graduated in Physics at Suez Canal University, Egypt. In 2009, I obtained my PhD at the Sir Peter Mansfield Imaging Centre (SPMIC) in a multi-disciplinary project bridging MR Imaging techniques with food sciences. My research focuses on optimising non-invasive MRI images and developing analysis methods to understand the physiological mechanism involved in food intake, food choice and consumption. This includes functional MRI to study the brain's perception to taste, aroma, flavour and oral fat emulsions; the physiological mechanism involved in satiation through brain-gut interactions; and the effect of taste phenotype and genotype on food perception, preference and choice. Following my PhD I worked as an

Assistant Professor of Physics in Egypt for four years. In 2014, I re-joined the SPMIC to investigate how different tastes are represented in the primary gustatory cortex "gustotopic mapping", using high resolution fMRI at ultra-high field (7T). This extended to understand how gustotopic maps differ with individual variation in taste phenotype and genotype (PROP and thermal taste). I also investigated the brain's response to phantom taste elicited in some individual "thermal tasters" when their tongue is thermally stimulated. Building on my previous research, I am currently optimising MRI techniques to combine brain and gut imaging in a single MRI scan session.

How did you become interested in the idea of mapping food in the brain?
I was always interested in studying the human brain, because it is such a black box. The human brain is a highly complex organ, and the recent development in imaging techniques provides new insights on the brain structure and function. My journey in studying the brain started by investigating the brain perception to visual stimulation in Egypt, however this was limited to animal studies using electrophysiological recording (EEG) rather than imaging techniques due to the limited research facilities. When I joined the SPMIC for my PhD studies, I investigated the auditory perception in the human brain using simultaneous recording of EEG and fMRI. I then moved into understanding food-related brain perception using fMRI. It is a very interesting and challenging area to study.



Is there anything particularly interesting you've found around food and the brain?
The more I do, the more I find interesting. I have learnt a lot through collaboration with sensory and food scientists. It is not just about how people perceive taste, it is more about how people are different – supertasters and non-tasters; thermal tasters and non-thermal tasters or, as I have recently learned, sweet likers and fat likers. Using brain imaging to understand individual variations in food perception is novel, and the fMRI group in Nottingham is world-leading in this area, hence a fascinating area to explore. There is a lot more to research. I am very interested in using imaging techniques to understand the individual variability in food perception, why people taste foods differently, and how the brain reacts to this. All the areas I've worked on are novel. This has provided me with a fertile environment for further research which aims to enrich our understanding of food perception. My current research is exploring this further through combining brain and gut imaging with sensory perception and taste phenotype to underpin the real drivers for food intake. Combining brain and gut imaging in a single MRI session is a novel technique that will enhance our understanding of the physiological mechanism of appetite and satiety in healthy and obese participants, and will pave the way to treatment and prevention.

Is there any particular reason why you wanted to join Future Food?
Joining the Future Food Beacon has been highly beneficial to my career. For example, I was allowed the opportunity to develop my own research, bridging food sciences and nutrition with the world leading state-of-the-art MR Imaging techniques at the SMPIC, which will allow me to establish myself as an independent researcher nationally and internationally.

Where do you get your inspiration from? I work with a great team at the SPMIC. They are always inspiring me around what to do, they are always looking for what is new. Working at the Sir Peter Mansfield Imaging Centre is in itself a great motivator. At his funeral, the words that really spoke to me were about the legacy he had left. When you think about the MRI discoveries and techniques he left after he passed away, how much they help different people, in medical fields and others... I would love to do something that will help people in the future; seeing how you can use science to help people – it is not just something you do as your job. That is my inspiration.

> "I was always interested in studying the human brain, because it is such a black box."

Do you have a greatest career moment?
I've had a very rewarding academic career so far, with several exciting moments. Some relate to research results, and some relate to the interaction with other academics and students. My favourite moment was when my research first got accepted for publication, and I witnessed the impact of my research on the scientific community and general public.

Do you have any advice for young scientists?
Be open minded. Work hard. Focus. Be patient. Keep looking forward. Don't give up.

What does your typical day look like?
I walk my dog in the morning and then I head to work. I have a normal academic life. My dog has forced me to get off my laptop more frequently, and get some fresh air.

How would you explain your research to an ordinary person?
My research focuses on using non-invasive MR imaging techniques to understand food perception and intake in the brain; why people taste foods differently and how the brain reacts to this.

How do you think your research will affect ordinary people?
The mechanism of neural interactions between sensory (mouth), brain and gut in the regulation of food intake is complex and remains poorly understood in obese individuals. To date, no study has assessed the whole picture of food intake (mouth, brain and gut interactions), and researchers have been looking at bits and pieces. Dietary fat is a fundamental contributor to the selection of food largely due to its pleasant sensory characteristics. Consequently, high fat foods are often over eaten leading to weight gain. Understanding the sensory-brain-gut interactions in response to a fat meal, will help inform the reformulation of reduced-fat foods that mimic the brain's response to high-fat counterparts and guide future interventions to reduce obesity. I will develop and apply imaging techniques to investigate the neural connection between the brain and gut in obese cohorts and normal weight controls, and correlate these measurements with taste phenotype. The outcome from this research will provide a step forward in understanding the physiology of food intake, food choice and consumption, and understanding individual variations in food perception, and alterations with obesity and in clinical conditions. The developed imaging techniques have the potential to be used as experimental tools to validate new food ingredients and evaluate the efficacy of palatable nutritious food, thus informing foods' industrial product design. The technique is providing platform technology to evaluate the efficacy of dietary, behavioural and pharmacological interventions in obese and non-obese patient cohorts.

Dr Sina Fischer

Sina Fischer is a Nottingham Research Fellow in Functional Genomics. 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.

What do you do and how did you end up at the University of Nottingham?
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.

How would you explain your research to an ordinary person?
For a non-science person this means that I am using the model species, *Arabidopsis thaliana*. It is a weed that we use because it is fast growing, it is small and it is easy to handle in the lab. It stands in for other species that are more interesting like wheat, I am using this to research what happens to a plant when it duplicates its entire genome. *Arabidopsis thaliana* usually has two sets of five chromosomes, so ten chromosomes, and the duplicated one would have twenty chromosomes. We saw that these plants have more potassium and they produce more seeds under salt stress. More seeds is the same as fitness and in a way is also the same as yield because for example for wheat, the seed is the thing that we eat. So this is an interesting trait and we want to understand the genetics behind this. Which genes are causing this? How did you get involved in this research? I did my Bachelors and then my Masters thesis in genetics. I studied flies and chromosome segregation in flies and how faithful chromosome segregation is maintained in mitosis. That was really interesting and I really enjoyed working with that. It was very focused on a teeny, tiny aspect of cell biology, which was chromosome segregation. Although this process is hugely important in cancer studies and has a lot of impact because of that, if you are studying one tiny protein in this whole process, it is still very far away from the big picture. So I was looking for something that for me, has a larger potential to impact human health and well-being. I joined the Department of Plant Physiology. This work is ultimately about the production of sufficient quantity and quality of food. I think feeding the world is going to be very important. In the end that is why society entertains scientists! It is a luxurious position to be in, working in this field. I think society has to have a reason why they keep us around! There should be some real gain beyond just increasing knowledge. We should keep this in mind and work on solving real problems, even when we are doing basic research. It is all important and will all contribute somewhere down the line but I think more and more modern science is about having a real impact.

How do you think your research will affect ordinary people?
I think it will mostly affect the breeding processes which could affect ordinary people because it will continue to provide sufficient food in a changing environment.

Where do you get your inspiration for your research?
I get it through reading papers and finding ideas from other people's work. When you go to conferences, that is where you see cool research that you've never seen before. I went to ICAR (International Conference on Arabidopsis Research) in Turku, Finland, and there was a person talking about his research in beech. He was studying different cultivars that grow in more and more tundra-like environments. The less woody it gets the more different the species becomes. He was also looking into tetraploids there, so perhaps there is potential for a collaboration in the future? Just generally hearing the different research that others do is inspiring and makes you think about your own research from different angles and perspectives.

> "There should be some real gain beyond just increasing knowledge. We should work on solving real problems."

Do you have a greatest career moment so far?
My PhD viva would be it. Stepping out of that room after the defence, being able to tell people I'd done well. That was really great.

How does being based here, with the Future Food Beacon, help you achieve your goals?
There is a really huge network here. I've always been involved with very condensed projects but it is very very important, vital, for a researcher to have a collaborative network. Nottingham in general, but especially the Beacon, has enabled me to meet other researchers, talk about their projects, start new projects. The Beacon has really helped, and is helping, me to develop this network.

Do you have any advice for others, young PhDs or students thinking about science?
For young students, thinking about doing a PhD, I would say you have to keep in mind that a PhD is generally self-motivated. In the end, what really drives your project is you deciding to do the experiment today. You have to be structured. You have to be able to do your work without supervision and without constant approval. There might be long time periods, months, where you don't get the big breakthrough and nobody is there to tell you, yeah this is good or keep doing this. Sometimes for weeks and weeks all you do is measure plants, and it is not really glorious and it is not very interesting. You have no idea if you are going to end up with a good output so you have to be able to work self-sufficiently, from your own motivation for long stretches of time. It's like a marathon. You cannot see the goal. You don't know how far away it is. And sometimes someone keeps pushing it further and further back. But you still have to treat it like an endurance race. You have to keep going, keep pushing yourself. So my advice is try and figure out if you are that kind of a person, if you can do this, or if you'd rather have rewards at the end of every day.

What does your typical day look like?
I come in in the morning, I check my emails, see if I've missed anything super important during the night. Sometimes I have experiments planned that take a while to set up, then I'd go straight to the lab and prepare those. I'd come back to the office, do some analysis on the computers, prepare figures, do statistics. Then go back to the lab, do more lab work and harvest seeds in-between. It really depends. If you have a specific technique planned for the day, then you might spend the whole day at the microscope. It can be very varied. I sometimes spend weeks doing computer work and analysis, planning for the next strategy.

Is there anything in particular you're looking forward to?
I look forward to the travel because I think I will have great travel opportunities with the Beacon. I'd like to move from working with *Arabidopsis thaliana* only and go to rice and barley as well. We have great collaborative partners who work on this here in Nottingham but also elsewhere. For rice, we are trying to establish collaborators in China. Once I have more groundwork done on this idea, I will be able to go out to meet with these collaborators and do fieldwork there. For barley we have collaborators in Australia so establishing those connections, and then maybe visiting these places, is something I am looking forward to.

Guillermina Mendiondo is a Nottingham Research Fellow in Crop Molecular Genetics, and a member of the Future Food Beacon of Excellence. Guillermina's research focuses on the impact of environmental stress on plant development, and the role of the N-end rule pathway in targeted proteolysis as a central hub integrating plant responses to abiotic stresses. She is particularly focused on agriculturally important crops like barley, identifying how the plants sense environmental changes that affect yield and crop quality. Her research aims to provide plant breeders with plant genetic resources tolerant of environmental stresses. Dr Mendiondo is an applied plant biologist with a background in molecular and crop physiology. Guillermina works in both the lab, and in the field, trialling plant lines she has developed in realistic scenarios.

Dr Guillermina Mendiondo

Why Nottingham and why the Future Food Beacon?
I truly enjoy working in this multidisciplinary place where different subjects combine to produce high quality research. For example, in my crop science studies, which are mostly based in molecular biology approaches, I have the opportunity to collaborate with plant physiologists, ecologists, soil scientists, and bioinformaticians. As a Nottingham Research Fellow I benefit from great facilities and really helpful technical support. As an early career researcher, I also benefit from the University's mentoring system which truly supports my career development. The School of Biosciences is currently involved in several doctoral training partnerships and, for me, being a PhD supervisor is one of the most rewarding parts of being an academic.

The people that you work with make a huge difference to how you feel inside an institution. I am very grateful to the many colleagues who helped me start and develop my research career in Nottingham.

I am happy and proud to be part of one of the University of Nottingham's Beacons of Excellence. Belonging to the Future Food Beacon community will bring me amazing opportunities, and gives me a sense of belonging. My project aligns very closely with the vision of Future Food. Given expected global population growth and the challenge of climate change, my aim is to understand the biological mechanisms that regulate crop response to environmental stresses and ultimately control yield stability and crop quality.

How would you explain your research?
I am interested in plant-environment interactions; how plants sense environmental change. I am currently identifying promising proteins that affect yield and crop quality in agriculturally important crops, such as barley. Also, I am interested in the hormonal regulation of seed dormancy and germination.

My research has a direct impact in the plant-breeding industry. My work opens the way to the development of crops with increased stress resistance and yield stability in both marginal lands and areas greatly affected by climate change.

What inspired you to pursue this area?
I grew up in a city surrounded by an active rural area. My childhood memory of the smell of grain after harvest is still very present. I also remember how the mood of the city was affected by a bad or good year, as the economy of the city was very much linked to the productivity of the fields. I have a degree in Biology but then I moved to Agronomy for my PhD program. I like applied science and crop sciences offered me the best of both worlds. I was inspired by many great people including supervisors and mentors. I enjoy the daily life of plant science research, including the laboratory, the fields and even the relaxing moments!

How do you move between being in the lab and being in the field?
I find it completely natural. I really enjoy it. I don't like routines so sometimes I am working in the lab, then in the afternoons I'll be in the field. Then I might have to look at phenotyping aspects of the plant. The way the plant looks gives you a lot of information about what is going on. As scientists we often look at things quite narrowly, people are incredibly focused on one tiny aspect of the plant, but I really like jumping between the field and the lab. That has given me extra skills.

How will your research affect the average person?
I feel privileged to work towards food security within the realm of sustainable agricultural practices. My research may lead to the production of crops with increased drought tolerance and/or lower water demands during cultivation. This is a pioneering study in the field of crop science. The plant lines I am developing will be tested in the field, as opposed to laboratory conditions. These non-GMO [non genetically modified organism] mutant plants, hold altered components of N-end rule pathway. Changes to these cell proteins used by plants to sense and respond to their environment – such as water and oxygen levels - have already shown increased tolerance to abiotic stresses like waterlogging and drought.

What's been the greatest moment of your career so far?
I had several exciting moments in my research career; some relate to research results and some to the interaction with the research community and students.

How will being based at UoN and joining the Future Food Beacon help you achieve your goals?
Joining the Future Food Beacon has been highly beneficial to my career. For example, I was allowed the opportunity to create my own research group where we conduct research at the highest level. It allows me to capitalise from my previous collaborations with the industry as well as with several international universities.

What aspects of your research and role are you looking forward to?
I aspire to establish my position as an international crop science researcher based at the University of Nottingham. As a crop science researcher I will direct my studies to the improvement of livelihoods and increased food security. This way I will be giving the community something back for the many opportunities I have benefited from so far.

Dr Michael Pound

Michael Pound is a Nottingham Research Fellow in Computer Vision. Mike is a computer scientist whose research focuses on the development of novel computer vision techniques. Within the Beacon, he is working with bioscientists to apply these computer vision techniques to plant phenotyping, providing accurate measurement of 2D and 3D shape information of plants. The bioscientists can use this information to explain the underlying mechanisms for how plants grow. Dr Pound has developed tools that allow biologists to measure plant root systems. These have been adopted by researchers all over the world.

What is your role with the Future Food Beacon?
As a Nottingham Research Fellow, I will be developing and applying modern computer vision techniques to the challenging domain of plant phenotyping. If we are to understand plant development, we must be able to measure them quickly and accurately. I will be working on numerous projects within the Beacon, bringing modern computing power to bear on tasks that would otherwise take hundreds of hours for humans.

Why Nottingham and why the Future Food Beacon?
Nottingham is a world leader in plant phenotyping. The University has long-established collaborations in this area, and the Hounsfield Facility offers state-of-the-art facilities for root imaging in soil. I will be working to match these facilities with equally accurate shoot imaging techniques, both within glass-house and field environments.

How would you explain your research?
Despite recent advances, computer vision still lags some way behind the human visual system. We can compare and measure objects very quickly, usually from a single angle. Humans can even do this with extremely complex objects, such as plants. However, it's not feasible for a person to sit and measure thousands of plants every day, we need ways to automate this. I work jointly with bioscientists to apply modern computer vision techniques to their challenging images, providing accurate measurement of 2D and 3D shape information of plants. This information feeds back into their research, where they use it to explain the underlying mechanisms of how plants grow.

What inspired you to pursue this area?
I find that working in a collaborative area such as this offers me the chance to address interesting problems with real-world impact. I also get to work with a variety of world-class researchers from many domains, which ensures that my work is always engaging and rewarding.

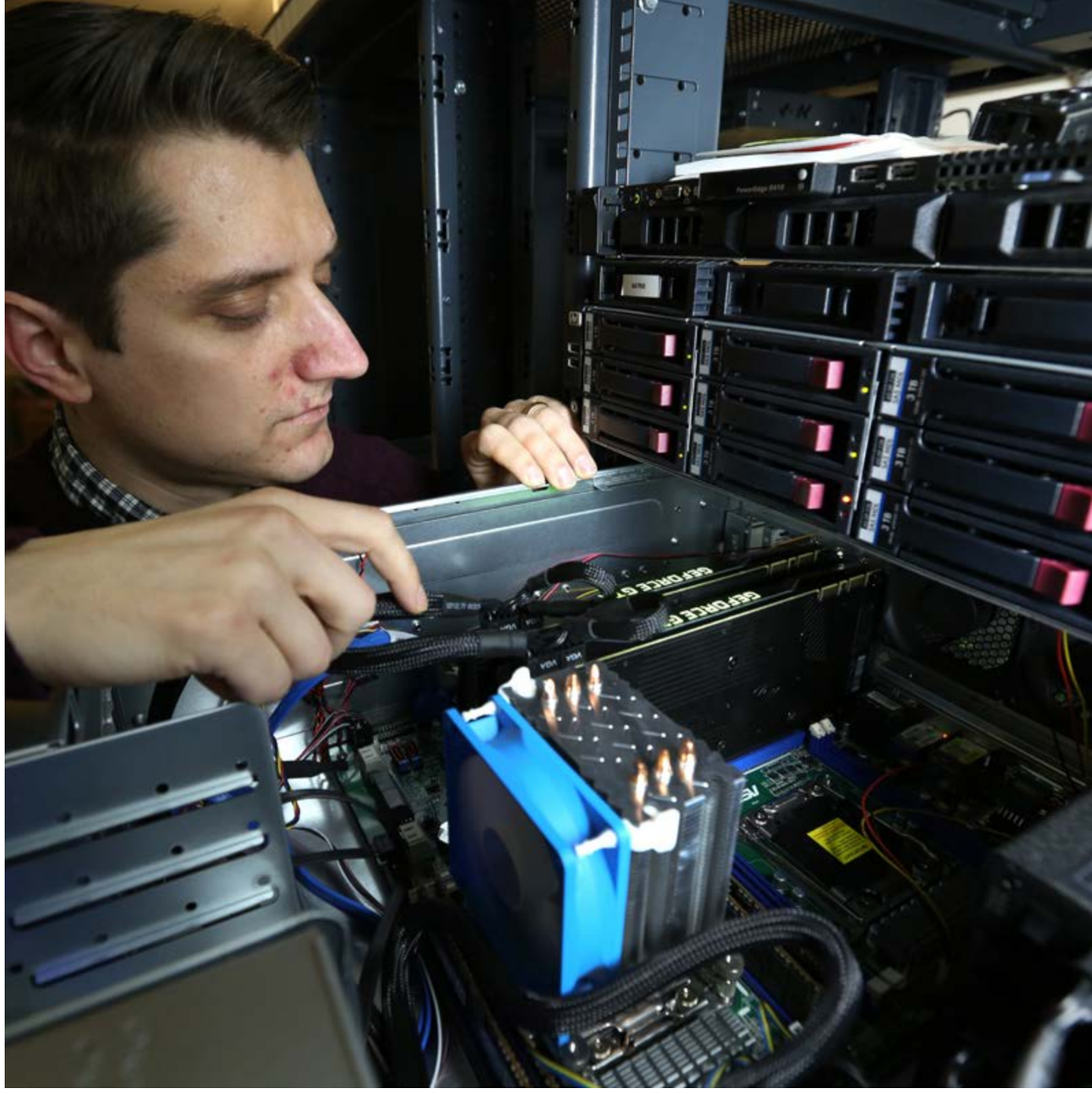
How will your research affect the average person?
Data from my imaging approaches will be used to inform plant breeding and genomic research. In turn, this research will have a huge impact on the ongoing problem of global food security. Developing bigger, healthier plants that can grow in challenging environments is a pressing issue, but one where we can have huge impact. Novel imaging approaches I develop can also be used outside of plant imaging, such as in medical image analysis, further benefitting the public.

What's been the greatest moment of your career so far?
I've had a very rewarding career so far, throughout my PhD and time as a post-doc. Perhaps my favourite bit was when I released some new tools based on my algorithms, allowing biologists to quickly measure their root systems. Very quickly these tools were adopted by the research community, they have now seen thousands of downloads and are in use throughout the world.

How will being based at the University of Nottingham and joining Future Food help you achieve your goals?
Nottingham has world-class facilities to support my research. The Future Food Beacon will allow me to collaborate with a variety of researchers from different backgrounds, on new and exciting projects. The Beacon also has a strong mentoring program, which will allow me to establish myself as an independent researcher within the University.

What aspects of your research and role are you looking forward to?
I am very excited by the idea of using new deep learning approaches to drive automated camera equipment. Fixed cameras have limited our ability to collect the best images, I believe that we can transform image capture using new artificial intelligence methods. This is also a very interesting research question; can a computer learn to perform the same task as an expert human operator?

The Future Food Beacon will also support a very wide variety of projects, I will be able to attend workshops and foster collaborations with more researchers, applying for funding and building a team to take on these interesting and important challenges.

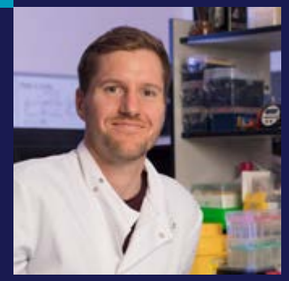


Interviews with our researchers

Meet the Future Food Beacon Technologists

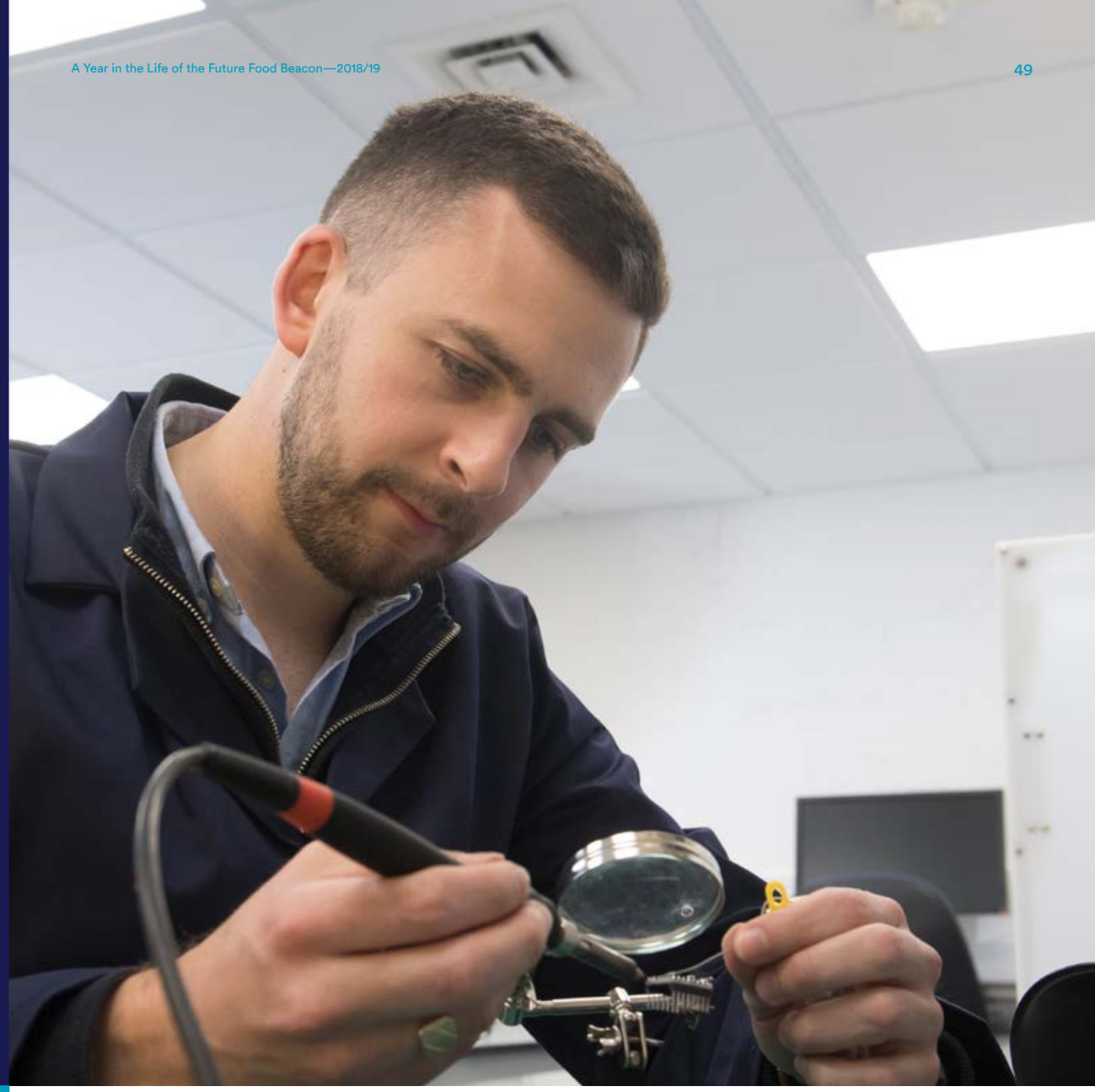
Dr Jonathan Atkinson

Dr Michael Wilson



Dr Christopher Moore

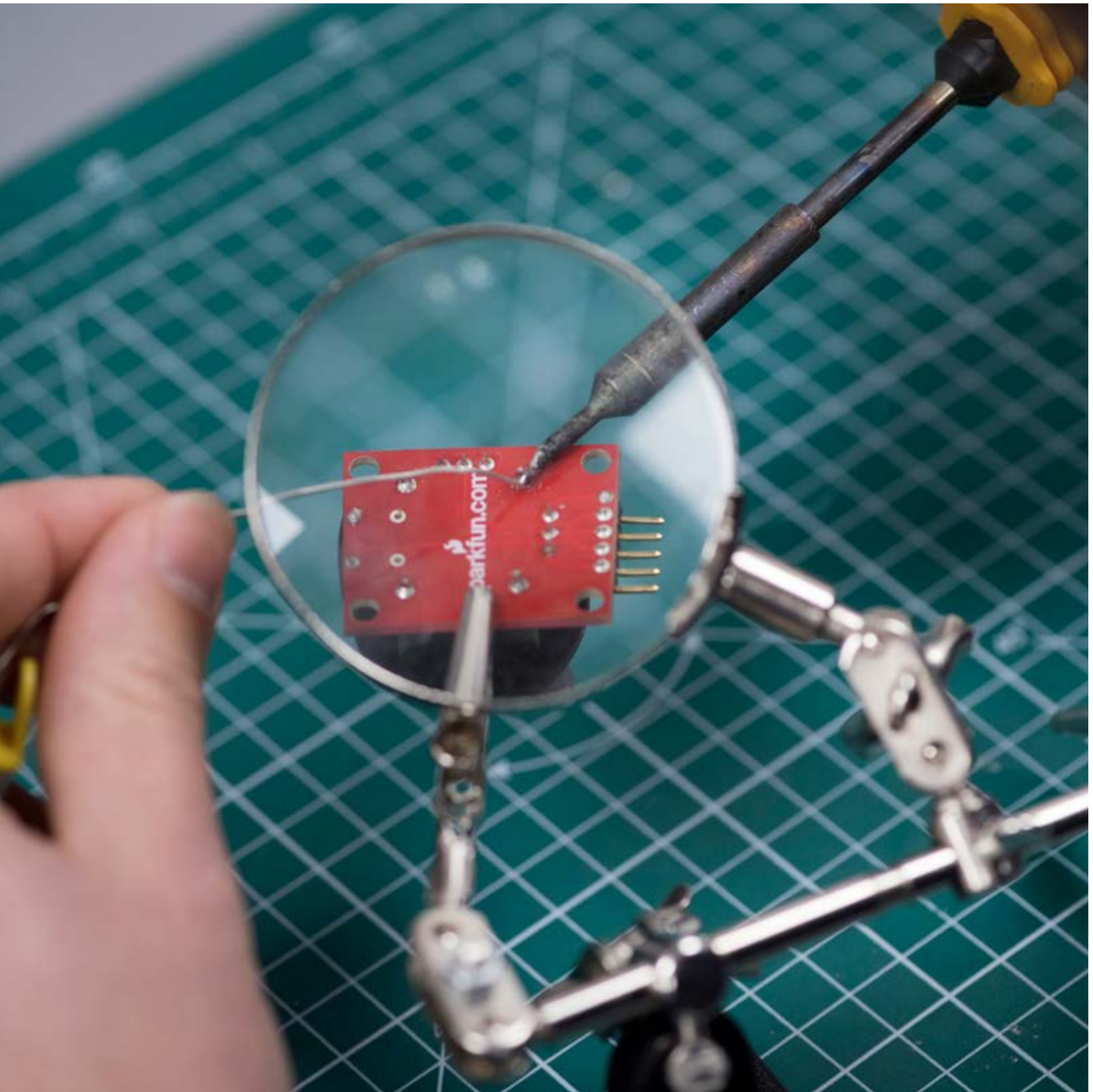
Jon Atkinson is a Senior Research Fellow and Technologist in Phenomics. As well as conducting his own research, his role is designed to help other researchers do their research by developing phenotyping equipment and kit. He will be working in the dedicated makerspace that has been developed within the Future Food Beacon. His previous research was focused on wheat roots, examining ancient relatives of wheat, and phenotyping cross breeds of modern wheat with ancient varieties.



Dr Jonathan Atkinson

Tell me about your role here?
My job is to be there as a service, and help people with their plant phenotyping problems: to build pieces of kit, to help other researchers with that. So if someone has something they want to do, I can help by building a piece of kit to do that. We have a lot of resources in the maker space with tools and 3D printers, that will help with that process. I am also continuing my own research work, in the area of root physiology and root soil interactions.

How did you become involved in this kind of work?
I fell into it a little bit. I did my undergraduate, my PhD and my postdocs at Nottingham. While I've been doing that I was always developing phenotyping kit for whatever project I've done.



What are you researching?
I've always worked on wheat before now, so all my previous projects were wheat-root related in some way. I've always specialised in looking at ancient relatives of wheat. Wheat is really genetically bottle-necked because it has a complicated evolution and it has been domesticated. That has forced it down a certain path which means the variation is quite a lot less than other crop species. Ian and Julie King run a programme where they take relatives of wheat, ancient varieties, and cross it into modern wheat to try and bring back more genetic variation. I will be continuing with this research but also branching into the genetic controls of root architecture.

How do you describe what you do to an ordinary person?
It is looking at an organism to observe it's characteristics, and then you try and relate that later back to something genetic that you can manipulate or understand. Most of it is just clever ways to observe things or measure them.

What kinds of things do you design to help researchers do their work?
It covers all sorts. The simplest things will just be camera rigs, pointing the camera or sensor at an experiment to acquire data at certain intervals. There are different levels of that, you can get robotics, things like XY gantries that move over plants, image canopies, glasshouse robotics, robotic arms, different types of imaging. It can be small things too, like flow cells.

Why did you decide to move into this role and join the Future Food Beacon?
It is kind of like my perfect job! I've always loved building things. If I wasn't doing Plant Science I would probably have been an engineer of some description. I've always tried to build and make things. I've always tried to add it on to whatever job I've done here.

How did you end up in Plant Science?
Complete chance. I did Applied Biology at the University of Nottingham and just liked plant science the most out of my modules. I ended up pushing the focus that way, as much as they'd let me.

How does your research affect ordinary people?
You'd hope that the research outputs from the research in some way would one day affect ordinary people. I think a lot of it depends on application. My previous postdoc was on designing future wheat, which is the BBSRC's central wheat funding. That is directly applicable. You get stuff going to breeders straight away, whereas other stuff might be 20 years down the line. It all filters in eventually, it's just the immediacy of it is different.

How does being based within the Future Food Beacon help you achieve your goals for the future?
It's a cool project. The scope is massive. It is possible to come up with ideas and try and follow something. You're more flexible to follow whatever comes up. I'll get involved in loads of different projects as well, bit by bit. It's a good way to do things, instead of the normal, more rigid structure of a conventional postdoc. You can do more blue sky thinking.

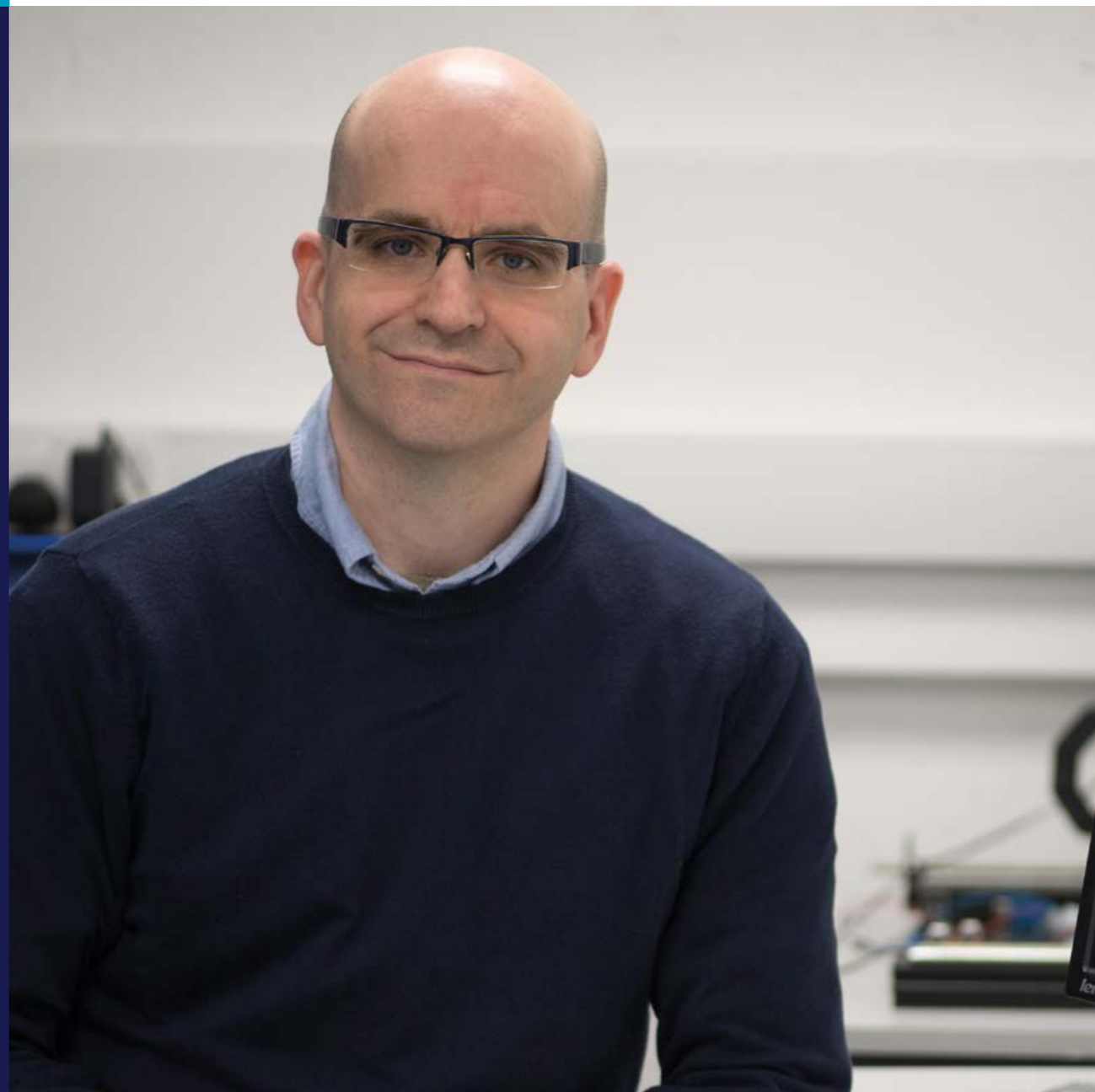
Do you have any advice for others?
If you don't love the science, it is not a career I would recommend. It is a bit of a slog at times. You have good days, bad days. You might spend six months working on something and the data sucks. You feel like you've wasted it. It is not always easy. But if you love the science, it is worth doing. I think I've been quite lucky with my career path so far, where I've just always fallen into things. It's hard to give people advice other than just plug away, and be a decent person.

Any career highlights?
Getting this job! There is always the worry that you end up stuck in a postdoc bubble forever, because there are so few positions that go past that.

Dr Michael Wilson

Michael Wilson is a Senior Research Fellow and Technologist in Bioinformatics. Michael handles sequencing data, data derived from the DeepSeq facility, and conducts integrative analysis. His role is to support biologists in handling the large amount of data to be produced. Michael is also responsible for the digital requirements of the Future Food Beacon. Dr Wilson joins the Beacon from the University of Leeds, having previously worked for the University of Nottingham at CPIB.

Tell me about your role?
As a bioinformatician I handle all the Next Gen sequencing data for the Future Food Beacon, considering our investment in the DeepSeq facility, this should be quite substantial over the coming years. I handle all the derived data from that, together with ADAC. We do the genomic analysis and identify tools or scripts or devise new approaches to analyse the data. I handle the digital requirements for the Beacon too; so talking to Dr Darren Wells about the data from sensors for the phenotyping, and lots of things like that. It is broad.



What were you doing before?
I started way back in the late 1990s at Leeds University. I did my PhD in Molecular Biology. I fell into Bioinformatics, because I did a fellowship after that where we were sequencing a gene, looking for polymorphisms in relation to heart disease. I fell in love with Bioinformatics, handling the data, looking for gene variations, processing genes... I then started an MSc in Bioinformatics at the University of Manchester and from that went to work for University of Manchester as a bioinformatician. In 2007, I joined CPIB at the University of Nottingham as a bioinformatician, supporting CPIB's requirements for the whole of its five years. I then worked with Malcolm Bennett before moving to the University of Leeds.

What drew you back to Nottingham and the Future Food?
This place feels like home. The breadth and depth of work happening here, you are drawn into various things that peak your interest. I've not known a place quite like Nottingham for that.

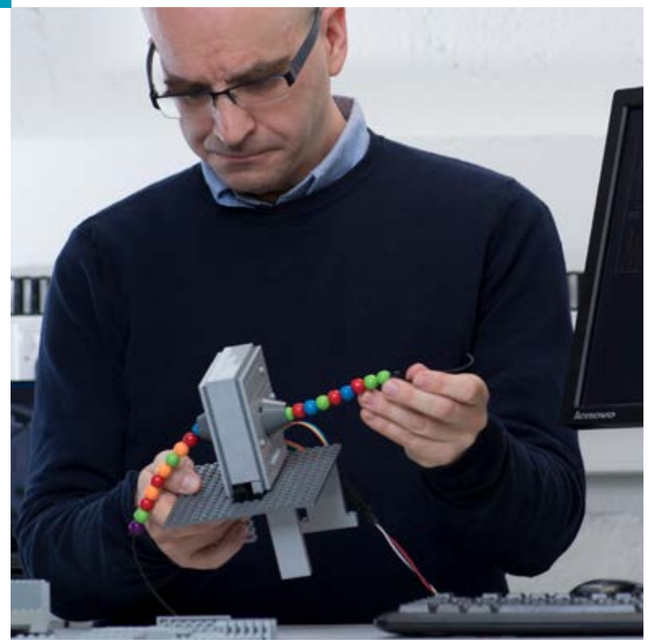
How do you explain what you do to ordinary people?
People understand biology but they don't really understand the scale of the data of biology. It is getting that across that is a challenge. My role is to handle things for biologists when it gets out of hand. Biology is such a broad topic and it is always, always developing, and it keeps getting bigger and bigger. My role is to take the pain away from the size, and answer questions, simple questions, from complex sets of data that have been generated.

"Bioinformatics is at the heart of most biology because the questions are so broad and so vast"

Does what you do affect ordinary people?
Bioinformatics is interesting, I always see it as the glue. It is the core of everything. We glue things together, whether it be data or scripts or just ideas. I struggle to think of a day to day thing where bioinformatics alone has played a role but bioinformatics is at the heart of most biology, even if it is not specifically mentioned. Most things that people understand, where biology has made an impact on their life whether it be understanding the human genome, understanding a crop genome, things of improving crops, feeding the world, responding to climate change, bioinformatics is at the heart of that because the questions are so broad and so vast. They can't really be answered without somebody like me, somewhere in the chain. The things that do affect people's lives don't happen without bioinformatics, certainly in the last ten, fifteen years.

Do you have a greatest career moment?
The most recent thing is always the peak I think. If you'd asked me two years ago, the work we did with Dr Ute Voss on the circadian clock was the pinnacle. But they are always so different and it's so hard to compare things. We see things as just broad strokes, and we will focus down on the detail, but we often don't really see the whole big picture. The most recent thing has always been the biggest challenge, and the biggest reward, and that is the way it should be. The most fun I've had was building the Lego Hounsfield!

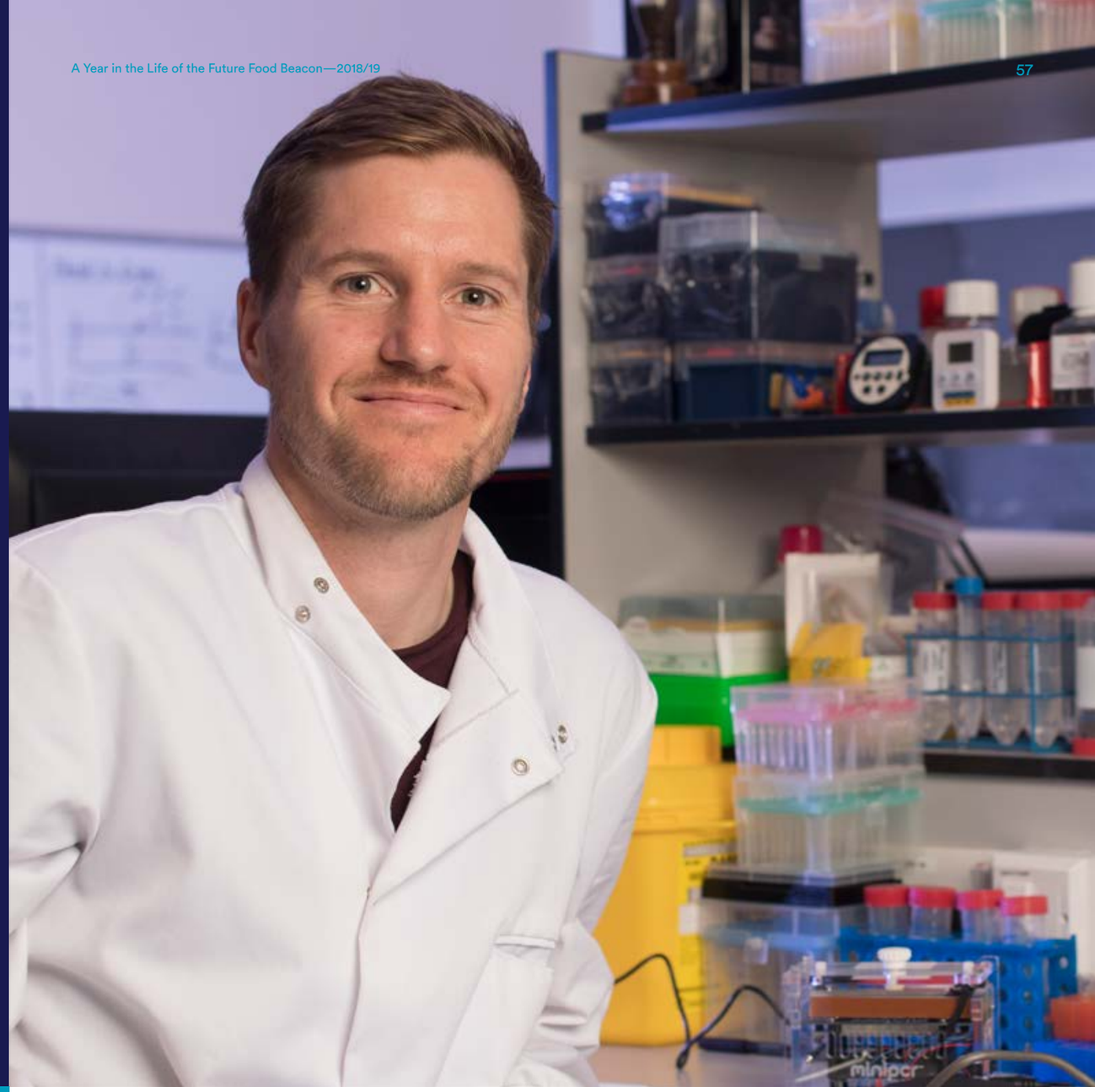
What does a typical day look like for you?
I start the day checking emails, then I sit down at a computer and will do a large amount of incredibly hybrid tasks, whatever is necessary. I'll get up and talk to somebody, go see Darren Wells or Jon Atkinson, talk to people in ADAC and we will talk about what is happening, what they're doing, and will see where things can go. It is always about talking to people, even or especially who aren't even necessarily remotely doing what you do. It is the discoveries, the things that flow out of that, that are the most interesting parts of this job. The real breakthroughs come from people talking to each other, and you can see where your work fits in, and where you can help in and out. That is very interesting. There is no average day. What is on the screen varies so dramatically. That is what keeps me coming back, the broad variety.



Do you have any advice for others looking to go into your field?
People have different definitions of bioinformatics. It is an incredibly difficult field to stay abreast on, so I would say pick something that is interesting and stay focused on it. Somebody will be interested in that technique, that skill. This job is in a bioinformatics/analytics centre – ADAC – and supports ADAC so that if there are things where I am not necessarily the best placed person to help, I can seek out someone with that skillset, because it is such a broad school. Knowing who to talk to and finding someone who can help is important.

How does being based within Future Food help you achieve your goals?
Being in the Future Food Beacon, what is being planned, what the Future Food leaders are envisaging is going to happen in the Beacon is very much something I want to be on board with. The vision people have, the expertise they have, is incredibly exciting. The breadth and depth of what is being planned is exciting too. It is something where I think I can make a big difference, with what I've done in my career so far, I think I can help these people really take us forwards in new directions. It is a very exciting place to be, and a position to be in.

Chris Moore is a geneticist and the Future Food Beacon technologist. He is based in Deep Seq, where he performs DNA sequencing and provides genomics support for Future Food researchers. Chris helps researchers to plan their sequencing projects, carries out the lab work and transfers data to bioinformaticians, such as Michael Wilson, for downstream analysis. Previously, Chris was a Research Fellow in the School of Life Sciences at the University of Nottingham.



Dr Christopher Moore

Tell me a little about yourself and your research
I did my PhD at Nottingham, which focused on the genetics of muscular dystrophy and the evolution of the genes involved. Since then I have had a number of different postdoc positions, all involving molecular and developmental genetics. Most recently I was working on a multidisciplinary project investigating the potential for using predatory bacteria as an alternative to antibiotics. This involved investigating host-bacteria and bacteria-bacteria interactions in a zebrafish model system through microbiology, microscopy and RNA-seq as well as working closely with a mathematical modeler.

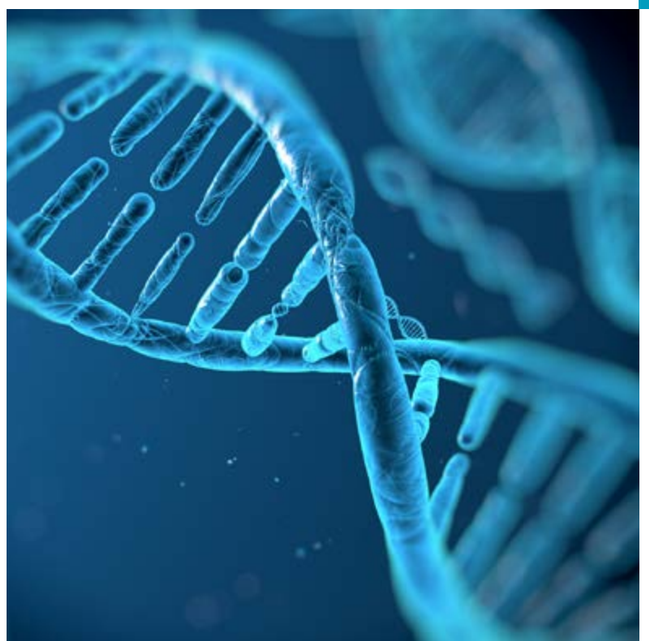
What are you going to be doing now?
I have got quite a diverse set of projects coming up. Currently I am working on sequencing a range of crop and livestock genomes, identifying organisms involved in cocoa fermentation and identifying bacteria in soil and how they affect nutrient uptake. I have also been putting together a portable field sequencing kit, which will allow researchers to perform DNA sequencing outside of the lab environment. It was a really challenging brief to fulfil, but it is incredibly satisfying now it has come together. The kit is initially going to be used to sequence samples from Colombian cocoa farms and then will be available to other Future Food research projects.

How did you become interested in genetics?
I was interested in biology and wildlife from an early age and always used to be peering into ponds or hunting under logs for amphibians, reptiles and minibeasts. However, it was in the first year of my degree that I really became fascinated by genetics and I realised that that was what I wanted to do. From then onwards I was hooked and my interest has increased with each project I have worked on. We are currently in a really exciting time for genetics, with great leaps forward in technologies leading to exciting discoveries, but also presenting new challenges. So it is a great time to be a geneticist.

What was the appeal of joining the FFB?
It was a great opportunity to be involved in a diverse range of exciting research projects, all of which have important real-world applications. I am used to being part of one or two projects in a lab, so being involved in so many is pretty amazing. Working within Deep Seq also gives me a chance to use a lot of cutting-edge technologies, such as longread DNA sequencing, robotic automation, optical genome mapping, single cell RNA sequencing and linked-read DNA sequencing.

How do you explain your research to ordinary people?
The production of any of the food that we eat involves at least one living organism and in most cases many organisms contribute. These organisms are influenced by their genetic make-up, so by understanding the genetics of these organisms and how their genes affect them we can better understand food production and how to improve it. That is where my work fits in. My role is to find ways to extract and decode this genetic information so that it is in a form that researchers can use.

Do you have any advice for young people interested in becoming scientists?
Do something that interests you and excites you: that's what keeps you going in science. When working in science things won't always go right, but if you're excited by the subject, the results, or the process then it is much easier to overcome these challenges.



"We are currently in a really exciting time for genetics."

Do you have a greatest career moment?
I don't think I have a single greatest career moment. There is work that I am proud of and papers that I put a lot of work into, but I think it is the combination of all the small discoveries and achievements that makes a career.

What is it like working in Deep Seq?
Deep Seq is a really great environment in which to work, with a lot of experience and knowledge in the lab. We are constantly busy with lots of diverse projects going on at any one time, which means that no two days are ever the same. Matt Loose (the Director of Deep Seq) has an infectious enthusiasm and it is hard to not get excited by the work we are doing.

Tell me about being a technologist. What does that entail?
My role is to facilitate researchers' genomics projects, from discussing their needs and drawing up quotes to carrying out the lab work and providing them with data. It can involve a lot of problem solving. I deal with lots of different types of samples from different sources, which means there is not a "one size fits all" approach when it comes to analysis. My role is also about getting the most out of the equipment and facilities we have to give researchers the best possible data for their projects.

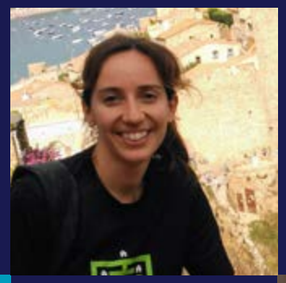
What are your long-term plans?
I would like to continue working in the field of genomics for the foreseeable future. I've always been interested in method development, so I would quite like to eventually move in that direction either in academia or commercially.

The Beacon is committed to developing an open research platform for researchers to work together on issues that span the food system. To enable such collaborative working, we host visiting fellows for various periods of time to work on different projects. We also work with different organisations to link producers and makers together.

Interviews with our researchers

Meet the Visiting Research Fellows and Collaborators

Dr Tereza Campello



Dr Silvia Busoms

Dr David Gopaulchan

Tatiana Chavez

Luisa's Vegan Chocolates

Dr Tereza Campello

Dr Tereza Campello was the Minister of Social Development and Fight against Hunger in Brazil, from 2011-2016. Dr Campello formulated and coordinated the Brazil without Extreme Poverty Plan, which contributed decisively to the elevation of 22 million people out of extreme poverty. She coordinated the Food and Nutrition Security National Policy, which saw Brazil's removal from the UN World Hunger Map in 2014. Dr Campello is the author of Faces of inequality in Brazil: a look at those left behind. We are pleased to welcome Dr Campello to the Future Food Beacon as a Visiting Research Fellow in 2018/19. While in Nottingham she will be working on issues of food justice and equitable development. She was part of the judging panel for the Future Food Innovation Challenge and will continue to participate in Beacon activities during her time with us. Dr Campello is hosted in collaboration with the Rights and Justice research priority area, by Dr Karen Salt.

Can you tell me a little about yourself?
I have worked in government all my life, since becoming an economist. In Brazil we have municipal, state, and federal governments, and I had the opportunity to work in all of them. I experienced how cities work by working with the state government, and how federal government works in a country the size and complexity of Brazil. I worked in financial areas with participatory budgets. That was a very interesting experience because it became the most important participative experience in budgeting in public policy in the world. It was very interesting because I could see how the people in very poor areas could understand and learn very quickly, and

A Year in the Life of the Future Food Beacon—2018/19

“To change the situation, you need to do things with impact, and think in terms of the people, not in terms of money or success.”

have ideas about how to solve problems. You can really share technical experience, and popular knowledge. It was a very important moment in my career. After that I worked coordinating areas in the centre of the government. In the federal government I was an aide of President Lula.

Tell me about the Bolsa Familia Programme?
I was part of the group that built up a cash transfer programme called Bolsa Familia; now it is the biggest cash transfer programme in the world and the most successful. The project is most interesting in terms of health and education, because those are some of the conditions for the cash transfer. The project has been running for 15 years so it is possible now to have evidence based in research about the impact in different areas. For example, a study published in The Lancet, showed that we could reduce child mortality caused by malnutrition in 58% of children participating in Bolsa Familia , in comparison to other children [1]. Currently in Brazil there are 14 million families in the programme. We never imagined we could reduce these issues so much! There are conditions attached to the programme – children have to go to school from when they are 6 years old to when they are 17 years old. Children have to join the health system once they reach six months of age. Then we can follow their health through their lifetimes. The family accompanies the child, and then the doctor can also monitor the family.

To change the situation, you need to do things with impact, and think in terms of the people, not in terms of money or success.

Tell me about your other work?
As an aide to President Lula, I worked with biofuels, other environmental and sustainable solutions in energy. I worked between agriculture, the environment, and small farmers. It was important to have an inter-disciplinary view of these areas.

How did you become interested in working for government?
I was a very lucky person. I finished my course the same year that the dictatorship in Brazil ended. We had a new constitution, and new progressive governments in some municipalities. It was an opportunity to try to change the country. I started to work in Porto Alegre, in the south of Brazil, and I just stayed working within different aspects of government. It is part of my identity. From there I understood that to change the world, you need to have scale. To change the situation, you need to do things with impact, and think in terms of the people, not in terms of money or success. I think all governments must do these things. Now, as a researcher, I am always questioning what I can do to help the government make good decisions. I think about scale and impact all the time.

Can you tell me about some of your other projects and programmes?
An interesting programme I led was a programme to build cisterns for people in the north east of Brazil. Brazil has a big area (four times the side of the UK), which is semi-arid. Some of the people in the area are very poor, and they have no water. It is impossible to supply water because the families are very spread out, and it is impossible to have a pipeline. So we built this cistern programme, in collaboration with the people living in the area, and an NGO network called ASA (Semiarid articulation). We delivered 1.2 million cisterns to the people. It benefits around 5 million people in the area. We also ran a very interesting programme around food and education. In Brazil, food in public schools is free, and we have 43 million children in schools from Monday to Friday. The main idea is: if it is possible to feed children in a healthy way, during this period, you can protect them. In the free school programme we decided that 30% of the food bought with federal money must to be bought from local, small farmers. It is fresh foods, vegetables, fruit, rice, beans, chicken. We also organised a programme to build kitchens because some schools had no kitchens to cook the food. Then we could tackle different problems. We created a permanent demand for small farmers so they could increase production. Children gained access to healthy food during school, and it was culturally appropriate and seasonal too.

Children are important to the success of these types of programmes. I worked on the programme against tobacco in Brazil, and it was a very very successful programme. In the 1990s we had approximately 37% of adults as smokers, and now we have less than 10%. That is a very important transformation. The children were a vehicle against smoking. “Dad! Don’t smoke, you will die!” and that kind of message. They can do the same with food, learning to eat fruits and vegetables at school and then wanting to eat that at home too.

What are your plans for the year?
I am working on a project proposal with Anne Touboulic, David Salt, Karen Salt, and the Future Food Beacon. The project will develop a methodology to map areas in large and medium-sized cities, where people have little or no access to healthy foods. It will focus in particular on low-income areas. For example, many people do not have access to refrigerators or only a very small one. So they cannot buy a lot of food. It gets wasted. Or if they are able to buy food, they have no storage for it. In general, people also run out of money at a certain point in the month. It is very difficult.
An example in Brazil are favelas. They are located in high hills, and are concentrated with people. Woman have to go to work at 4 in the morning, take a bus or train for 2 hours, and come back very late in the evening with the children. They have no place to buy things. A long time ago we had little groceries with fruits and vegetables on all the corners. Now all the corner stores are filled with biscuits… You can buy junk food on any corner in a favela but you have no place with fresh foods. Then it is impossible for the mother to cook fresh food. The project will map these “food deserts” and will also map the best practices to inspire solutions to solve the problem.

Another plan is dedicated to understanding the relations between poverty and inequality. In general, we think poverty and inequality are the same thing. But they are not. People think about poverty and inequality through understandings of income. But poverty, inequality and hunger are all complex, multidimensional phenomena. I am hoping we can organise a kind of matrix, helping us think about these three problems, understanding how different access determines each. For example, if you do not have access to a refrigerator, what impact on hunger, poverty, and inequality does this have? If you are poor, and have no access to electricity for example, it is more difficult to change your situation. People often criticise poor people for being lazy. But they are not lazy, they have no opportunities! They have to think about what they are going to eat tomorrow. They have no time to make plans and organize solutions to get out of poverty.

How can we think about inequality in terms of poor people? For example, access to water, – that is not income and yet it can change people’s situations. The FAO have a new report showing that hunger is increasing in the world again. It had been falling for a long time, but has started increasing again. This is not because of a lack of technology, or climate change… In different parts of the world, social programmes are being cut and people are less well-off, including here in England. This is having adverse effects on our health too.

Sometimes a person may suffer from hunger and malnutrition, and obesity at the same time. It is not simple.

Food is a right. But it is a financial problem too.
What are the long-term costs of hunger, poverty, obesity? We can end hunger and reduce malnutrition with the technology we have available now. We can produce healthy food. We have enough food in the world to feed everyone. We know what we need to do. We have solutions. Scientists and research can help governments and politicians to make the correct decisions but it is a big challenge for us today.

We have no time to waste to transform the world, because we have problems with food, with climate change, and we need solutions quickly.

“We have no time to waste to transform the world, because we have problems with food, with climate change, and we need solutions quickly.”

David Gopaulchan is a postdoctoral researcher in the molecular lab at the Cocoa Research Centre, University of the West Indies. He recently completed four months as a Future Food Beacon Visiting Research Fellow, working with colleagues in Biosciences to sequence over 250 varieties of cocoa bean in order to establish if there are genes involved in Cadmium accumulation in cocoa plants.

Dr David Gopaulchan

How did you become involved in cocoa research?
I always had a passion for genetics, molecular biology and biochemistry. For this reason I pursued my bachelor's degree followed by a Ph.D. in those fields, at the University of the West Indies. On completing my degrees, I saw an opportunity at the Cocoa Research Centre (CRC). They were looking for someone to DNA fingerprint the International Cocoa Genebank in Trinidad and other cacao germplasm worldwide using SNP markers.

What brought you to the University of Nottingham?
Cadmium (Cd), is a major problem for cocoa growers at the moment. It is a heavy metal that can accumulate in plants and be stored in their edible parts. When we consume cadmium contaminated foods, it accumulates in our body and over time can lead to a number of diseases. Cocoa is a known accumulator of cadmium, as the plant absorbs the metal and stores it in roots, shoots and beans. We use cocoa beans to make chocolate, and therefore high levels of cadmium in cocoa beans have become a food safety concern and the reduction of cadmium in the beans to minimize human intake is an important issue. The European Union has developed regulations that set maximum allowable limits for cadmium in chocolates, which will be implemented in January 2019. When implemented, these regulations will negatively affect the export of cocoa beans from Latin America and the Caribbean, which have excessive cadmium due to high quantities of cadmium in the soils. Latin America and the Caribbean are the principal regions producing fine/flavour cocoa and these new regulations will impact on the livelihood of thousands of small-holder cocoa farmers as well as the European chocolate and confectionery sector. Fine/flavour cocoa is different to the bulk cocoa grown in West Africa. Fine/flavour cocoa produces complex flavour profiles in chocolate, and is predominately used in the bean-to-bar and artisan chocolate sector.

My present research involves developing strategies to mitigate cadmium accumulation in cocoa beans so that they will be safe for consumption. The research is focused on exploiting genetic differences between cocoa varieties in absorption and sequestration of cadmium into beans. The CRC is the custodian of the International Cocoa Genebank (ICGT), which has over 2400 cacao varieties, and is regarded as the most diverse cocoa collection in the world. The genetic resources and phenotypic information at CRC are being used to develop a novel genetic solution to the problem of elevated bean cadmium affecting cocoa growing areas in Latin America and the Caribbean.

Professor David Salt, the director of the Future Food Beacon, is a leading expert on cadmium accumulation in plants and has a team of experts in the areas of genetics and ionomics that can help me develop solutions to reduce cadmium levels in cocoa. The project utilises the strengths of both institutions: the technical expertise at the Future Food Beacon and the genetic resources and phenotypic information at CRC, to develop a novel genetic solution to the problem of elevated bean cadmium. We are sequencing 250 varieties. We are examining the genotype to understand if there are any genetic markers that can be linked to cadmium. Once the markers are identified, we can find the genes that might be responsible for cadmium uptake. If we can identify the genes, we can use that knowledge to develop a DNA test to screen varieties to see if they have the markers for high or low cadmium. We can then select varieties with low cadmium uptake and use them in breeding programmes.

How do you work with farmers to develop solutions to problems like the one with cadmium?
We actively engage farmers and they are involved in the discussions that address the issues the industry faces like elevated cadmium. They form part of the stakeholder groups that help focus attention on tackling these problems. Additionally, the CRC has been working with farmers in developing strategies to mitigate the accumulation of cadmium using soil ameliorants and cultural practices.

Did the research come about because of the new EU restrictions or is it something you were concerned about any way?
It was something that we were concerned with, however, the restrictions forced the industry and research community to act more quickly and invest resources towards developing solutions to reduce cadmium. At CRC, a lot of what we do is influenced by the needs of the chocolate industry and the public, and the quality of beans is a major area of concern.

What are you hoping to do while at UoN?
The DNA sequencing and ionomics facilities at UoN are very impressive, and the researchers are highly trained, friendly and open to sharing information. I am therefore trying to learn as much as I can as we advance the research. I am also trying to network and build connections and improve the collaborative links between the CRC and the Future Food Beacon. I do not see this as a one off project, but rather the beginning of a partnership to address the problems the cocoa industry faces.

What is your long term plan?
I would like to further develop my research skills and experience to support the sustainability of the cocoa sector. This would involve moving cocoa into the modern breeding arena and providing support to the cocoa breeding industry, through the development of molecular markers for a range of important traits.

Dr Silvia Busoms

Dr Silvia Busoms is a plant scientist and Future Food Beacon collaborator. She earned her PhD from the University of Aberdeen and the Universitat Autonoma of Barcelona in 2015. From 2016-2018, she was a postdoctoral researcher in Levi Yant's lab at JIC.

Tell me a little about yourself and what you do?
I studied forest engineering at the University of Lleida in Catalonia, and I worked as a forest engineer for a while, first for a private wood company and then in a national park. I did enjoy that but then the crisis started in Spain and I had to look for other options. When I was doing my degree, I always was passionate about plant physiology and genomics. The Universitat Autònoma of Barcelona (UAB) advertised a grant funded by the National Institute of Health. I applied for that and I received it so I could then do a Masters and a PhD in Plant Biology. I was supervised by David Salt, who was at the University of Aberdeen at that time (currently Director of the Future

Food Beacon, University of Nottingham), and Charlotte Poschenrieder at UAB. The project was about the genetic basis of natural ionomic variation. I am very grateful to both because I could learn a lot about plant physiology in Charlotte's lab, different genetic techniques during my stays at David's lab in Scotland, and get a PhD from both universities. After that I joined Levi Yant's group as a postdoc at the John Innes Centre (JIC) in Norwich where I continued my research in salt adaptation.

How did you first get interested in forest engineering?
I wasn't sure about just doing biology. I always liked plants but I was also interested in engineering. It was a good option to mix both of those things. Forest engineering allows you to be involved in conservation, ecology, … with a solid mathematics and physics base and I was really interested in that.

What was it like moving from being a forest engineer to being a plant scientist?
I miss some of the "more direct" applicability of the forest engineering but, although I am not working with trees at the moment, the fundamental science we do can involve or be reproducible in any plant species so I hope farmers and conservationists will benefit from our research results.

You are currently working on a really interesting site in Catalonia, can you tell me about it?
Our aim is to take advantage of the natural variation that exists in wild populations of *Arabidopsis thaliana*. In Catalonia, *A. thaliana* is quite rare. It is not like the UK, where you can find it everywhere, so this means that we have environmental factors that limit the existence of this plant. We decided to do an exhaustive survey in this area and we realized that soil composition is mainly determining the distribution of this species. On one site, we could select coastal and inland populations that show clear differences in salinity tolerance and, on the other site, we have a gradient of populations showing the different ability to survive in alkaline soils. Both stressors are problems that affect farmers around the world so the possibility to identify and study plants that have evolved and adapted to these harsh conditions has a lot of potential.

Can you tell me a little about your recent paper that was published in PNAS?
I started this work during my PhD and I completed the genomic analysis during my postdoc at JIC. First, to prove that the *A. thaliana* plants from coastal populations were locally adapted to the coast and study the mechanisms they use to tolerate saline soils we performed several field and lab experiments that were published in a previous paper (Busoms et al., 2015). Then the next objective was to investigate the genetic variability driving this adaptation and one of the candidate genes with several polymorphisms was the sodium transporter HKT1;1. The selection and maintenance of the different variants of HKT1;1 alleles, detected also in other coastal European populations, could not happen just by chance so we decided to focus on the causes and effects of the allelic variation identified in this transporter. We integrated a genetic, physiological and ecological approach to understand the role of HKT1;1 allelic variants in the adaptation to the fluctuating salinity dynamics we have in Catalonia but the work is not finished yet.

What is the potential for this work in the future, do you think?
When we discover genes that have evolved and been selected in well adapted populations, we have two options for improving the sustainability of crop yields: look for cultivable varieties that have mutated in a similar way, or use gene-editing techniques to create varieties more adaptable and resistant to these abiotic stresses. The work has real, worldwide implications for growing food under the variable conditions that are a consequence of climate change.

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What is the advantage of using plants that are natural variants, in a natural laboratory?
The advantage of working with natural variants is that we can identify the agent responsible for a selection pressure, soil salinity in our case, and do genome scans to look for the regions and genes that are unique in the adapted populations. The advantage of working in a natural laboratory is that we can do real reciprocal transplants in the field, test if the local adaptation is real, and observe the behaviour of the plants that are variants for a single gene. Moreover, with natural variants we can study the evolution and migration events of candidate genes. For example, we were expecting that the *A. thaliana* we found would be quite prevalent in Catalonia, or similar to the Iberian relics that are around Spain but most of the plants have a similar genome to the European varieties. This migration/adaptation is fascinating and we want to follow up this study.

What are your plans for the future?
At the moment I am in a transition period, where I am applying for various fellowships. During my postdoc at JIC I started a promising project on a new model system, *Brassica fruticulosa*, also related to salinity tolerance, which I hope to finish this year here in Nottingham. I am also teaching in a summer school in Kenya this April where I would like to establish collaborations for future projects as well. My plan is to be based in Barcelona but to have tight partnerships at Nottingham. The facilities here for sequencing genomes, and the bioinformatic support, are amazing.

What advice do you have for young scientists?
I would encourage them to do what they like, what they are passionate about. Sometimes it is difficult, a research career is intensive and challenging; so if you're not motivated it can be painful. I would also advise younger scientists to not be afraid of travelling a lot, meeting new people, working as a team and establishing collaborations everywhere they can.

Do you have a greatest career moment?
I still consider myself a young researcher but, of course, the acceptance of this PNAS paper was fantastic news. It took a while but the effort was worth it. I am very excited about it.

How does your research affect ordinary people?
Now that we know that HKT1 is really helping the plant to tolerate salinity, it is good to look for the homolog of this gene in other cultivars. HKT1 is also present in rice and sweet potato for example, not just in brassicas. So, if we can find populations with HKT1 variants, we can select the ones that are more tolerant for salinity and cultivate those. In some agricultural areas, water used for irrigation is contaminated with salt, or if there are periods of drought, salts can increase in the soil and make it tricky for the plants to grow. It is not only a coastal issue, it can happen in many places, especially now that we are going through uncertain climatic changes. I could say our results have an indirect effect, if the plants that farmers are cultivating are more adaptable and resistant to periods of drought and salinity and other environmental stressors, then yields will be maintained or improved. This can affect food prices and that has implications for ordinary people.

Anything else?
I think there is a real need for knowledge regarding plant science to exist in the public domain and I am not sure how to fight for that. The companies that keep science private do not share their failures. If they could share those, people won't make the same mistakes again.

"I think there is a real need for knowledge regarding plant science to exist in the public domain."

Tatiana Chavez was a visiting researcher in the Future Food Beacon in February and March 2019. She is from Ecuador. She works in the Biotechnology Research Centre of Ecuador (CIBE), in the Molecular Biology laboratory. She currently researches the analysis of the expression of genes related to plant-pathogen and plant-biofertilizer interactions.

Tatiana Chavez

Can you tell me about your work and how you became involved in research?
I've been working in this field for almost eight years. During my Bachelor's degree (Biology), I started working on diseases associated with bananas. My research was focused especially on the interaction between banana and the fungus *Pseudocercospora fijiensis*. I've been working on that until now. Lately, I've been studying how a bio-fertilizer could control the pathogen infection (*P. fijiensis*), but would also fertilize the plant as an organic alternative; assuming that bio-fertilizer provides better growing conditions and may enhance self-defence in the plant. My research has always been focused in molecular biology and genetic engineering in plants, mainly with banana but also cocoa and coffee. I've started to work in cacao, focusing on cadmium absorption.

The physiological differences between cacao and banana have been the trickiest part for me to understand, but in the biological sense they are very similar. I am researching the genes related to heavy metal transporter pathways and how these are related – the interaction between what is happening outside and inside the plant.

How did you become interested in this topic?
I started working with viruses, particularly human viruses like influenza, but always from the molecular biology perspective, because that really fascinated me. I was focused on viruses in the beginning of my career because they are interesting. Then I had an opportunity to change the research to some viruses in plants. Later, I had the chance to work on fungus and plants, in order to learn about genetics, which was also motivating, so I switched to focusing on plants and fell in love with that. I first thought it would just be for my Bachelor's degree but I learnt a lot.

Cocoa is one of the most important crops in Ecuador, not only because of the quality of chocolate that we can produce, but because of the history and heritage of the cocoa tree to the Ecuadorians. In fact, plants are an important part of my life! My hobby is working with plants, reproducing them in my home. I have a huge space at home dedicated to reproducing ornamental plants and making plant arrangements. I have lots of plants at home!

How did you come to join us at the Future Food Beacon?
A soil science professor, Eduardo Chavez, in Ecuador, started working on the levels of cadmium in the soil, and the absorption of that element in cacao. He asked me and Professor Eduardo Sanchez (who I work with in the Molecular Laboratory in Ecuador), what we might do on a molecular level and we matched our ideas and knowledge, but at that moment it was impossible to get started. Later, he met Prof David Salt at a meeting in Peru, and they were talking about the possibilities for research in cacao and cadmium absorption with more clear ideas of what we can develop in this research as a team. So Prof Chavez introduced us (me and Prof Sanchez) to Prof Salt and we discussed the possibilities of a fellowship here and the scope of the research. I am here for two months, working on the issue of cadmium uptake in cacao.

How did you become interested in science and molecular biology?
I was really interested in the environment, contamination, and how we can decrease pollution when I started my biology career. But at university I had some subjects in molecular biology. I took on a fellowship to get experience in the lab, so it would be easier to understand the subject in the classroom. I really enjoyed the lab and got attached to the subject.

How has it been so far at the University of Nottingham?
It has been truly different. I did a fellowship in the US and it is even quite different from that. There are a lot of protocols and procedures just to get into the lab. We have weekly meetings and those have been a great experience. We share our progress and talk about what we can do to increase our progress for the next lab meeting. For me, that really helps my research move forward.

How do you think the research you do affects ordinary people?
The research I am doing now on cacao is hugely important – both for ordinary people who consume chocolate and for the farmers. The farmers need this research in order to export their cacao beans to Europe. Europe is the main consumer of cocoa beans in the world. There is a time importance to this research too. It is really important both economically for the growers, and for the health of consumers.

Do you have any advice for young scientists?
Don't be too hard on yourself, and what you want in the future. Every opportunity that you can take, take it. You can always end up on the path you want, even if you take a winding way to get there.

What are your plans for the future?
I would like to do my PhD. I hope to find funding to do so. I'd love to work on something that I could say I made a difference. I'd like to be a role model for young scientists and scientific woman in this field as well, especially since I come from a developing country.

Luisa's Vegan Chocolates

Luisa Vicinanza-Bedi is a chocolate maker based in Sneinton Market in Nottingham. Her company, Luisa's Vegan Chocolates, makes bean to bar chocolates using cocoa beans sourced directly from farmer's around the world. Luisa is collaborating with the Future Food Beacon on an Innovate UK project in Colombia.

Tell us about your journey into the world of chocolate making?
I started learning how to make 'bean-to bar' chocolate in 2017 on a laboratory scale cocoa processing and chocolate manufacturing line at a chocolate plant at the Science Park. This was after a year or two of making healthier chocolate treats from my kitchen and selling them to friends and at local small producer markets. At the time I was a teacher of Textiles, Art and Food, and I'd always had a love and appreciation of chocolate. My colleagues could always be sure I'd have a supply of high percentage chocolate in my work bag.

After becoming an apprentice, I embarked on a journey of chocolate discovery. The whole experience of making chocolate from the raw cocoa bean to chocolate was captivating. It was fascinating to learn that each cacao bean has a completely different taste profile dependent on the terroir (soil, temperature, humidity, flora & fauna) and good farming practices. All these conditions plus the way the cacao bean is fermented plays an integral part in the end taste of the chocolate we eat and enjoy. Creating super premium chocolate is 'all about the bean'. Without super premium beans to start, we can't do our magic.

My emphasis is on producing delicious high quality dark chocolate using directly sourced beans, and the exceptional tasting experience of my chocolate was confirmed upon receiving an array of awards; a great taste award, and three 2019 Academy of Chocolate awards 2019 including a prestigious gold award for my Philippines chocolate.

How do you ensure you get premium beans for your chocolate?
We work directly with our farmers and monitor the crop to ensure quality. All our farmers look after their cacao by well-spaced planting, multi-cropping with high canopy coconut trees to give partial shade to the delicate cocoa trees, and kitchen garden crops for their own use, thus ensuring an excellent long term sustainable environment that is full of diversity.

We also pay them a direct trade price more than two and a half times the average farm gate price, which we believe reflects the true value of the cocoa beans and is a better than fair deal for the farmers.

How do you go about testing the quality of the beans?
We conduct a "cut test" of all our cacao beans and check the moisture levels before we start roasting the raw whole cacao beans. Mass market chocolate usually involves only roasting the nib (fractured cocoa bean kernel) by first removing the outer shell of the cacao bean. This method results in a significant loss of flavour. It is critical that the fermentation process has been carried out correctly by the farmer if we are to create sublime taste notes in our end chocolate products. That, along with the correct roasting profile and other processes, will aid or enhance the flavours already present in high quality cacao. It is the skill of the chocolate maker to work with the magic of superb quality beans.

How do you go about making chocolate?
The process we follow involves roasting the raw cacao bean, winnowing to remove the outer shell of the cacao bean and then slowly conching in a stone grinding machine for days to release the flavours. This turns the cacao nibs into a chocolate liquid know in the trade as a chocolate 'liquor'. With the addition of a little cocoa butter and unrefined sugar the whole mix refines (ultra-fine small particle size for smoothness) and melds the flavours into the finished unique flavour of that single estate farm chocolate.

We use our winnower mix in teas to ensure there is zero waste generated from the excellent cacao beans. We hope to expand the uses of the 'cacao shell' and work to create some really exciting developments in the future.

Could you tell us about your experiences in Colombia?
Luisa's Vegan Chocolates is the commercial partner on an Innovate UK project to understand the importance of fermentation in the chocolate process, and to identify the microbes present during that fermentation. The project runs over threedifferent crop cycles, and this enables us to identify any improvements in the taste of chocolate arising from the scientific data and the related changes in the fermentation process. We travelled to Colombia in May 2019 to meet with our three female farmers. We are building a solid partnership with the farmers, and this will allow us to promote the Colombian cacao alongside the single-origin chocolates we already make.

Building a close rapport with the female farmers has enriched my practical knowledge of the fermentation process, and seeing the vital positive change farming cacao, and being paid a better-than- fair price for their beans, has made to the lives of each farmer, was the chance of a lifetime. Here at Luisa's Vegan Chocolates, we place an emphasis on ethical, direct trade of the beans, with each chocolate you purchase traceable back to the farm it was cultivated on.

What an amazing project to be part of, especially with the emphasis on female equality! A female run business in Nottingham working directly with female farmers helping to improve the prospects for these women and their families, and communities and making wonderful chocolate! What a match made in heaven.

Our projects 2018-19

Pearl millet in Senegal

By Malcolm Bennett and Ndjido Kane

We are excited to announce funding from The Royal Society 2018 International Collaboration Award scheme for the project entitled: ‘Anatomics in Pearl Millet: Improving yield and drought tolerance of a major dietary staple food in the Sahel’. This 3 year research project builds on the transdisciplinary expertise of teams co-led by Prof Malcolm Bennett at the University of Nottingham, and Dr Ndjido Kane of the Senegalese Institute for Agricultural Research (Institut Sénégalais de Recherches Agricoles).

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Pearl millet is a staple food for approximately 100 million people, and 90% is grown by smallholder farmers. Its grain is high in proteins, essential minerals, and energy. It is also gluten-free and contains hypoallergenic properties. It therefore has huge potential as part of a nutrient-rich diet, so it is crucial for researchers to better understand its properties. To facilitate this, an international consortium involving Dr Kane published the pearl millet genome sequence last year (Varshney et al. 2017). Later sequencing of a diverse collection of varieties revealed that pearl millet’s domestication occurred in West Africa (Burgarella et al. 2018).

Drought in the Sahel, a region bordering the southern edge of the Sahara in Africa, is a major hindrance to pearl millet production. As climate change brings unpredictable weather patterns and increasing temperatures, the need to select new varieties of pearl millet better adapted for future environmental scenarios is increasing.

As part of the international collaborative research award, the UK, Senegalese and French teams and their collaborators aim to identify varieties of pearl millet with improved root architecture and anatomical traits designed to improve resilience to drought stress. For example, selecting varieties with smaller water transporting vessels in roots would serve to conserve water reserves in the soil until later in the growing season when rain is limited and water is needed to mobilise nutrients into developing grains.

How will root imaging be done? Root samples will be collected during field trials in Senegal, then shipped back to a specialist facility at Nottingham. We will use a new high throughput anatomical imaging technique developed with US colleagues at Penn State (termed ‘anatomics’), where researchers use a high powered laser to cut and image many thousands of root sections in just minutes, then using advanced Deep Learning algorithms to automatically harvest data about key features such as cell number and size. The anatomics approach will enable researchers to rapidly screen varieties for desirable root anatomical traits from a diverse collection of pearl millet lines.

The ultimate goals of this project are to pinpoint the key genes that control desirable traits, share expertise, resources and data with research partners, breeders, and smallholder farmers, in order to advance breeding programmes, and develop more resilient crops. This will have real impact on the everyday lives of people living in the Sahel, and in other communities where pearl millet is grown as a staple crop.

The international collaborative research award is in addition to a new GCRF funded networking grant to both teams entitled “Enhancing pearl millet productivity and marketability in sub-Saharan Africa” that aims to develop sustainable partnerships, research exchanges, and capacity strengthening on pearl millet research with collaborators in Rothamsted and Institut de Recherche pour le Développement (France). It will support long term research exchanges and capacity strengthening between Senegal and UK expertise in nutrition, grain quality and brewing research areas to deliver added value to pearl millet.

CEPHaS: Understand soil water and its potentials for agriculture

By Murray Lark

Conservation agriculture (CA) is a set of practices which have been proposed to improve the resilience and sustainability of crop production, particularly in sub-Saharan Africa (SSA) where food security is endangered by the increasing frequency and intensity of drought seasons under climate change. In CA, the structure of the soil is not disturbed by cultivation, and crop residues and other biomass are retained on the soil surface to protect it against erosive rainfall and to enhance its carbon status. CA also relies on crop management (rotations and intercrops) to manage pests and diseases.

Our understanding of CA systems in Africa is limited, and there are particular gaps in our knowledge about the impacts of CA practices on soil physical properties and so on the water cycle as a whole. Do soils under CA have better water retaining properties? What are the effects of CA practices on the infiltration of water into the soil, and is the net effect on the recharge of groundwater resources positive or negative? This latter question is particularly pressing, because groundwater resources are critically important for many communities in SSA.

The CEPHaS project, funded by UK Research andInnovation's Global Challenges Research Fund (GCRF), is focussed on the development of research capacity in relevant branches of physical environmental science for the better understanding of CA practices. This is being done with a network of partners in Malawi, Zambia, Zimbabwe and the UK. The project brings together soil scientists, agronomists, hydrogeologists, geophysicists, statisticians,

and agricultural economists from the University of Zimbabwe, the University of Zambia, Lilongwe University of Agriculture and Natural Resources, the University of Nottingham, Rothamsted Research, Liverpool School of Tropical Medicine, and the British Geological Survey.

The CEPHaS project group is working on field experiments to compare conservation agriculture and conventional crop management. In Zimbabwe and Malawi CEPHaS is working on established trials, and in Zambia they have set up a new experiment. At all project sites CEPHaS is using both field-based sensors and laboratory methods to examine the behaviour of soil water, including realtime measurement of water content in soil profiles. Hydrogeologists in the CEPHaS project are also examining the groundwater, making realtime measurements in new instrumented boreholes. A particular challenge is to understand the connection between water in the rooting-zone of the soil and water at depth. We are addressing this with shallow geophysical methods, including novel technology for resilient and energy-efficient imaging of the subsurface developed at the British Geological Survey. This technique, called timelapse electrical resistivity tomography (ERT), will allow the team to visualize and quantify the wetting of the soil profile during rainfall events , and the redistribution of water to depth under CA and conventional management.

In addition to field and laboratory experiments, we are committed to training and knowledge exchange activities. Specialist training in near-surface geophysics took place at the British Geological Survey in Nottingham in 2018, and this was linked to field-work and on-the-job training in Lusaka and Lilongwe. This covered the assembly and installation of geophysical arrays and equipment. Similar on-site training has been undertaken in soil physics. There has also been training in statistical methods and further training in soil physics and hydrogeology is planned for later in the project. A team within the CEPHaS project has been tasked with reviewing CA practices from the perspective of farming systems and agricultural economics. CA cannot be understood purely in terms of the environmental and physical systems, it also has socio-economic implications, for example, for the labour requirements of farming and how this labour is divided between genders. An objective of the network is to ensure that the physical scientists keep this broader perspective while framing questions about CA systems.

The CEPHaS project also recognizes that the development of research capacity is not just about hardware and know-how. Institutional factors can affect the effectiveness of research groups. That is why the Capacity Research Unit at the Liverpool School of Tropical Medicine is part of the project, and is facilitating a structured approach to understanding and tackling issues in research capacity within the network.

Prof Murray Lark, the University of Nottingham lead on the project, explained that CEPHaS is important because of the pressing need for answers to questions about how land management can be made sustainable and resilient. He said, "we cannot develop resilient food systems and a resilient agricultural economy that provides livelihoods for farmers and food security in sub-Saharan Africa without a better scientific understanding of soil and crop systems. It is essential to develop the research capacity of international networks to tackle these problems. At the same time research in the physical and biological sciences must be done with an awareness of the social and economic constraints that farmers face. In CEPHaS we are trying to build the kind of multidisciplinary teams that can develop solutions to the complex and multifaceted problems that policy makers, NGOs and, above all, farmers, face in Africa today."

CEPHaS is an on-going project, now just entering its second year. By early 2019 all field sites will be fully-established and delivering data, and the ongoing research will continue through to the end of 2021. Prof Lark said, "our objective is to grow the CEPHaS network, building on our enhanced capacity, with further funded projects to deploy our approaches at sites across the region."

Innovations in agriculture and food for healthy societies: workshop report

By Future Food Fellows

We are a multi-disciplinary team of early-career researchers based in the Schools of Biosciences, Computer Science and Physics at the University of Nottingham. We are all Research Fellows in the Future Food Beacon. Our research focuses on delivering the global challenge of enough nutritious food for a growing population, produced in sustainable and ethical ways.

We were extremely happy to represent the Future Food Beacon at the Innovations in Agriculture and Food for Healthy Societies workshop in Shanghai, China. This workshop was funded by the British Council Newton Fund, and hosted by The University of Nottingham and Nanjing Agricultural University. The workshop aimed to foster new and exciting collaborations with partners abroad. The workshop brought together people from various research institutes and universities from the UK and China, and provided a wonderful environment for networking. Over the course of three days, we were challenged to identify potential areas for collaboration, particularly those that address current challenges in Chinese agriculture. We were then asked to develop solutions in the form of potential multi-disciplinary project proposals, and had the opportunity to pitch these ideas to a panel of experts.

The workshop began with high speed introductions, in which we were introduced to every other early-career researcher, their projects, their motivations and aims during intense five minute presentations. Getting to know each other helped us identify common interests and potential collaborators from the get go. The introductions also provided us with an opportunity to talk to each other, and understand each other's plans for our work in the Future Food Beacon. Some of us are new in post and this was therefore an invaluable opportunity to spend time together. During the first and second days, all attendees presented posters showcasing their work and research interests. This allowed a more informal discussion of potential areas of collaboration, and provided more time to expand on our work than was possible during the brief introductions.

Throughout the workshop we were guided by an experienced team of mentors from the UK and China including: Professor Nick Harberd, University of Oxford, Professor Fangjie Zhao, Nanjing Agricultural University, and Dr Levi Yant, University of Nottingham. Each mentor presented their own research in masterclass sessions, where they put particular emphasis on their journey from research bid to successfully funded project. We are all looking to forge successful independent research careers, and the advice of established academics is incredibly useful, and thought-provoking.

The remainder of the workshop was focused on establishing new collaborations between researchers in the UK and China. In teams, we explored potential projects, and began designing competitive grant ideas that will be taken forward over the coming months. The mentors helped us identify the strengths and weaknesses of our proposals, and hone these into more realistic and fundable projects. Spending this time with respected and established academics was extremely useful, they were able to provide insights into possible avenues for funding, and focus in on what parts of each idea were key to success. This kind of training is crucial for early-career academics in becoming competitive in this process.

The climax of the event was a pitch session, in which teams were able to present their projects to the group, answer questions, and receive feedback from the mentors, and from other researchers. This was extraordinarily helpful in making us think about the ways we craft and write research bids, and how we might do this better. We all left with a number of exciting avenues for future research, and we will be developing these ideas with the help of the Future Food beacon in the next few months.

The workshop was a highly interdisciplinary meeting, with researchers working in fields as diverse as agriculture, urban planning, law, human perception of foods, plant physiology, computer vision, plus many others. We really enjoyed the interaction with other conference delegates. We all learnt a great deal about the technologies and techniques that are currently used by other researchers to address the challenge of providing the world's growing population with a sustainable food supply. With researchers from a wide variety of fields, we were exposed to new ideas and viewpoints, all of which broadened our project ideas, helping us think outside the box more, and will contribute to our writing and research in the future.

A brief history of Africville, Nova Scotia

By Karen Salt and Lexi Earl

In this blog post we discuss the origins of Africville, a community in Halifax, Canada. Exploring the history of Africville was part of the Geographies of Black Protest research project conducted by Dr Karen Salt, Bright Ideas Nottingham (a social enterprise based in Nottingham) and colleagues, funded by AHRC as part of the network funding for the UN Decade for People of African Descent. In July 2018, the Future Food Beacon supported a return trip to Africville for Dr Salt and her colleagues, so that they could participate in the 35th anniversary celebrations of the founding of the Africville Genealogy Society. Africville has a fascinating food history, which Dr Salt is currently investigating.

This post forms part of our series on Food Stories, and our interest in lives lived 'on and in the margins'.

Africville was an African-Canadian village located north of Halifax in Canada. It was founded in the mid-18th century. Inhabitants of the village were Black Nova Scotians from a variety of origins including: runaway slaves, freed slaves, Black Loyalists promised land and/or their freedom by the British military for fighting against the US, and Jamaican Maroons. During the 19th century Africville grew and expanded with these waves of inhabitants and by 1917 had a peak population of roughly 400 families.

The rural community was self-sustaining, culturally rich, and had strong community ties. Alongside houses, the community had its own school, ice hockey team (the Africville Brown Bombers), the Seaview African United Baptist Church (est.1849), and many residents ran fishing businesses from the Bedford Basin. But as a community, Africville residents experienced constant economic exploitation by the City of Halifax, alongside governmental neglect of the environment which resulted in the systematic oppression of the Black community. For many, Africville represents the often ignored oppression faced by Black Canadians. Throughout Nova Scotia, Black settlements thrived, resisted and survived in challenging and hostile conditions. Although Africville provided the main impetus for the Geographies of Black Protest team, they recognise that it is only one of many stories that challenge the national myth suggesting that Canada is not a country founded on white supremacy, racism, and colonialism. During this visit, the research team were able to explore further links with communities in North Preston and East Preston.

Africville was a self-sustaining community. Local fisherman sold their catch locally and in Halifax. Other businesses included agricultural trade and small stores that opened towards the end of the 19th century. Africville became an escape from the anti-Black racism that permeated throughout Halifax and also provided opportunity for employment that were not widely available for Black citizens elsewhere.

Future proteins: Just crickets?

By Andy Salter

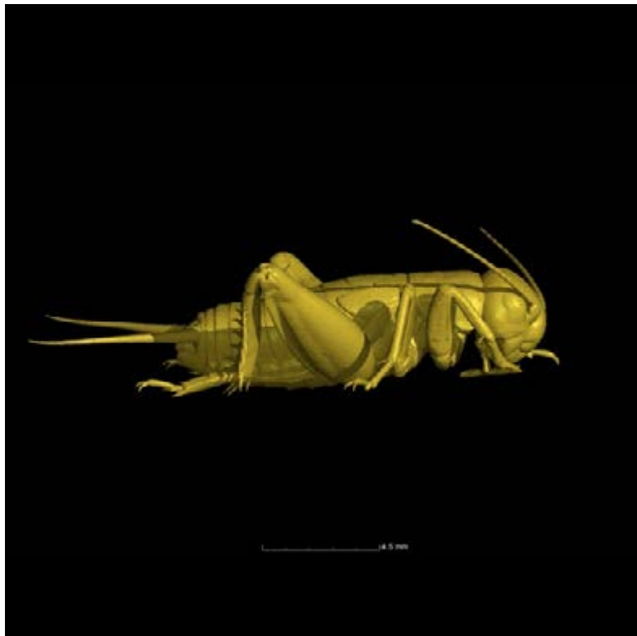
In October, a paper by Springmann and colleagues appeared in Nature setting out a rather bleak picture of the impact of future food production on the planet (https://doi.org/10.1038/s41586-018-0594-0). They concluded that by 2050, without mitigation, expected changes in population and income levels would lead to environmental effects that would be 'beyond the planetary boundaries that define a safe operating space for humanity' (p.519). This was based on the prediction that with greater economic stability the growing population would adopt diets richer in animal- derived food products. Such a shift has already been seen in many parts of the world, perhaps most notably in China over the last two decades.

This week the mood appears a little bit more optimistic with alternative protein sources hitting the news. The decision by Sainsbury's to start selling Roasted BBQ Crickets seems to have particularly caught the imagination of the media. Insects are seen as a potential source of high quality protein that have a considerably smaller carbon footprint than conventional livestock. While a 12g bag (retailing at £1.50) of about 50 crickets may be some way from solving our global food security problems, it is interesting how this has caught the imagination of the press and perhaps demonstrates a willingness, of at least some of the population, to try alternative, environmentally friendly foods. Perhaps more significantly, it was also reported in the press this weekend that Beyond Meat, a start -up company, supported by the likes of Bill Gates and Leonardo DiCaprio, was in the process of raising $100million to expand its activity in producing 'meat-like' vegetarian burgers using plant – derived proteins.

It therefore appears to be a perfect time for the Future Food Beacon to be launching its Future Protein Platform. The Platform, led by Professor Andy Salter is the result of a successful bid for £1million from the Beacon's Innovation Challenge this summer. The funding will provide two postdoctoral researchers and a number of PhD students to investigate the potential of a range of novel protein sources. Such protein sources will help to tackle the problem of producing sufficient protein to satisfy the population without the predicted catastrophic effects on the climate.

Recognising that it is unlikely that the whole world will turn vegetarian overnight, The Future Protein Platform will investigate not only novel proteins for direct human consumption, but also alternative sources for feeding livestock. Animal protein represents the highest quality in terms of both its amino acid composition and digestibility, but the livestock industry utilizes vast amounts of human edible crops as feed (like soya, wheat, and maize). Replacing these human-edible crops with more sustainable protein sources such as underutilized crops, insects, algae or even bacteria may significantly reduce the impact of animal agriculture on the environment. However, many of these protein sources come with problems associated with inappropriate amino acid composition, poor digestibility and associated antinutritional factors, which can affect the uptake of other vital nutrients.

The Future Protein Platform will combine expertise from across the University, from Plant and Animal Science to Food, Nutrition and Engineering to investigate how these novel protein sources may be manipulated to maximise their nutritional value for direct human consumption, farm animal production and aquaculture. A combination of such 'Future Foods' should be one way in which we can avoid crashing into our planetary boundaries!



Our Innovation Challenge: project announcements and reflections

By Lexi Earl

The focus of the Future Food Beacon is to find solutions to the twinned challenges of enough nutritious food for the planet under changing and increasingly testing conditions; and providing foods that reduce diseases of affluence, like diabetes and obesity. Our focus runs along two themes: agricultural resilience, and food for health and healthy ageing. We recognise that food is inextricably tied to production, management, policy, culture, and rights. In order to find solutions to these challenges, the Future Food Beacon established an Innovation Challenge which ran over the summer of 2018 and brought together over 200 researchers and practitioners from across the disciplines.

The aim of the Innovation Challenge was to create opportunities for stakeholders to come together and exchange ideas and approaches, methods and ways of thinking about food. From April to July, workshops were held across our international and UK-based campuses which brought researchers together to discuss how we might find solutions to the challenge of future food, and gave them space to make connections around their work so that the emerging projects were well-situated within an interdisciplinary approach. At project refinement workshops in July 2018, researchers were able to present their projects to an audience of peers, answer questions, and then make changes to their ideas and plans, further refining their goals and approaches. Final proposals were drawn up and then submitted.

The final step in the process was participation in a 'pitch' event in August. 11 project proposals were submitted to our panel of judges, and these were then invited to present their projects to the panel. The panel was made up of leaders from the food industry, academics from other institutions, and policymakers.

The event was hugely successful, with all projects being declared 'fundable' by the panel. The Innovation Challenge set out to fund two projects and the panel decided on the following projects:

'Future Proteins Platform: Enhancing the production of high quality protein from existing and novel sources', led by Professor Andy Salter.

'Palaeobenchmarking Resilient Agricultural Systems', led by Dr Matt Jones. This project emerged through a combination of Palaeobenchmarking Future Agricultural Resilience and From Darwin to Borlaug to Future Crops.

The other projects are being supported to help identify alternative funding opportunities to take them forward.

PhenomUK

By Tony Pridmore and Lexi Earl

You have probably heard of plant genomes right? Scientists sequenced the wheat genome back in August 2018. The genome is the genetic structure of a plant and understanding the make-up of the genome gives scientists a map to understanding how the plant is formed and maintained. But have you heard of the phenome? The phenome tells us about the structure and function of the plant, its shape, number and size of leaves, growth rate, resistance to disease… Without the ability to bridge the genome-phenome gap and relate physical and functional attributes to genetic structure the full benefit of genomic technologies cannot be realised.

Through phenotyping – the quantitative and objective measurement of plant structure and function – we can learn how well a plant might grow in various conditions in the field. Phenomic data gives breeders a toolbox they can use to select plants suited for a variety of climates; for example, plants that grow well in drought conditions, or can survive in salty soils.

Plant and crop phenotyping is not only a biological challenge but also a major technological one. Sensors are needed that can make reliable measurements of physically complex, living and changing plants growing in laboratories, glasshouses and fields. Data sets capturing key properties of roots, shoots, flowers, seeds and the like, must be recovered from those measurements effectively and efficiently. Cameras are widely used to gather data, and advanced computer vision techniques are needed to extract plant properties from the images they provide.

PhenomUK is a new UKRI Technology Touching Life network, led by Prof Tony Pridmore at UoN and Prof Malcolm Hawkesford at Rothamsted Research. Technology Touching Life is a joint initiative from BBSRC, EPSRC, and MRC that aims to harness new and emerging developments from engineering and physical sciences to advance discovery research in life sciences.

PhenomUK is the UK's national network on crop phenotyping. The network is interdisciplinary, bringing together engineers, physical and computer scientists to work with plant biologists to develop automation, sensors, and data analysis techniques capable of profiling plants in a wide range of environments. It will ensure that UK scientists have access to technological capabilities needed to drive world-leading discovery research in plant, crop, and agricultural sciences.

The network will also provide a deeper understanding of national plant phenotyping capabilities, needs, and opportunities, allowing the UK to participate fully in, and gain maximum benefit from, international initiatives such as the pan-European infrastructure EMPHASIS.

Interdisciplinary collaboration on plant phenotyping is increasingly important as scientists work to ensure sustainable, future crops that can survive in adverse environments, given the increasing population pressures on the planet coupled with changing climate conditions. Prof Tony Pridmore explained, "producing sufficient food to meet our needs is a global problem. Though plant and agricultural science are central to its solution, they alone cannot provide the phenotyping technologies that are urgently needed. PhenomUK's goal is to bring the UK's engineering and physical sciences and life science communities together around this key challenge".

How do you feed a mission to Mars?

By James Huscroft

In December, the University of Nottingham Division of Food Science, and the Future Food Beacon were pleased to host Dr Michele Perchonok, current president of IFT, to a lecture on the question of feeding the mission to Mars.

On Friday 14th December 2018, the University of Nottingham had the honour of hosting Dr Michele Perchonok who is currently President of the Institute of Food Technologists (IFT) in the USA. Prior to this position, Michele was the Manager of the Human Research Programme at the Johnson Space Centre for NASA where her responsibilities ranged from New Product Development (NPD) and processing requirements for space food, nutrition and menu definition to the realms of food packaging.

Dr Perchonok talked first about the IFT as an organisation, and what they do for students and

industry professionals. This includes opportunities for international collaborations, courses and networking events much in the same way the IFST operates here in the UK.

The main part of the talk was fantastic. No other word to describe it. Dr Perchonok talked about “Feeding the mission to Mars”; specifically, the challenges which might be faced. Currently, space missions usually last between 6 and 8 months. The longest time spent in space at present is a year on the International Space Station. Getting to Mars when the Earth and Mars are at their closest point in orbit (which happens once every 2 years) will alone take 6-8 months!

As food scientists, the main question we face is the logistics of food required for such an undertaking. Not only would food be required to have a shelf-life of 5-7 years (the predicted total length of any mission to the red planet) if it was sent up before the mission began, but what will happen nutritionally over the course of this shelf-life since nutritional quality is of major importance to the crew? These were just some of the questions posed by Dr Perchonok.

Dr Perchonok explained that we know the pleasure and taste of consumed food is majorly impacted by the aroma volatiles which enter the nasal pathway. Due to the differences in gravity between the Earth and Space, these volatiles may not enter the nasal pathway entirely and thus change the perception of the food when consumed. Other factors influencing pleasure and taste might include meal variation, colour and even familiarity of the food which must be considered if a 32-month mission is to be accomplished.

Dr Perchonok also spoke about the technology which may need to be implemented to make such a mission possible. Food processing, innovation and flavour must all be considered. Some ideas posed ranged from: microwave sterilisation to pressure assisted sterilisation technology, innovative foods and ingredients, to functional foods and even flavour/vitamin encapsulation to aid in the diets of the crew members.

One exciting, new technology would be the use of hydroponics and LEDs on the Martian surface. This would optimise space when astronauts were living on the surface of Mars and would allow them to actually grow something as simple as a tomato which we take for granted here on Earth! This would be slightly more challenging on the surface of Mars where the temperature is around -80°C! This is clearly going to require serious thinking.

The one thing that was clear from all this work was that food science is readily changing to meet the needs of some truly astronomical visions and that we, as the next generation of food scientists, are in for a true spectacle to meet these challenges and visions head on. New ventures, like the Future Food Beacon here at the University of Nottingham, along with other international collaborations show that these visions will become reality one day.

Lastly, thank you to Michele and to Bertrand Emond (current Chair of IFT British Section) for visiting us and sharing such a fascinating talk!

Giant swamp taro: crop for the future?

By Lexi Earl, Guillermina Mendiondo and Sofie Sjögersten

Giant Swamp Taro (*Cyrtosperma merkusii*) is an underutilised but highly productive plant native to the North Sulawesi region of Indonesia. It can grow up to 5 metres tall, and may produce tubers underground that are 2 metres in diameter and up to 3 metres in length. It grows in flooded, brackish conditions. This makes it an excellent plant to grow in areas where the sea is spreading inland, altering the salinity of the soils. Farming in this region of Indonesia is characterised by smallholder farmers, working marginal lands, vulnerable to unpredictable and decreasing yields in the face of wider climatic changes out of their control. Rice, a current staple crop, is vulnerable to salinity and therefore the cultivation is affected by sea incursions. (Some islands in this region are only 14 metres above sea level, and are therefore experiencing changing conditions at a rapid rate.)

Farming in this region of Indonesia is characterised by smallholder farmers, working marginal lands, vulnerable to unpredictable and decreasing yields in the face of wider climatic changes out of their control. Rice, a current staple crop, is vulnerable to salinity and therefore the cultivation is affected by sea incursions. (Some islands in this region are only 14 metres above sea level, and are therefore experiencing changing conditions at a rapid rate.)

A new project, funded by a Newton Institutional Link with Indonesia brings together UK expertise in wetland soils, plants and crops, cropping and agro-economical systems, and rural socioanthropology, with Indonesian expertise in biochemistry, plant physiology, market research, food technology, rural development and agricultural extension.

The goal of the project is to develop a food production model for giant swamp taro. At present, giant swamp taro is not consumed as a staple food within Indonesia because it is not currently grown as an agricultural crop. Little is known about giant swamp taro – there are no botanical descriptions, the genome has not been sequenced, and we do not know how flowers develop. Our basic understanding of where giant swamp taro grows, why it grows in particular places, and how it grows, are all missing.

However, there is much potential for the plant because it can be grown by small-scale farmers, even in conditions of climate change (due to its tolerance of salinity). Developing models for delivering food products from underutilised/ potential crops, such as giant swamp taro, will enable farmers to future-proof their livelihoods and food production in the face of harsher conditions and climates. Such crops can be grown sustainably, providing future foods that do not contribute to climate change.

The project focuses on a number of avenues in order to explore the full potential of giant swamp taro. The project will explore the growth habit and environmental tolerance of the giant swamp taro. The project will develop cultivation systems that allow the plant to be grown as a sustainable food source, including engaging directly with farmers to trial crop cultivations, and develop capacity in Indonesia. A key focus of the project is to increase food security in the local area, through exploring the use of these indigenous plants. The project will also, and possibly most importantly, develop options for marketable food products. This is important because it will impact on the sustainability of the crop for the farmers (by increasing their income), and will also allow the crop to be seen as a staple food within the community.

This project draws on researchers from multiple disciplines. It is led by Dr Sofie Sjögersten, Associate Professor in Environmental Science and includes Dr Guillermina Mendiondo (Crop Molecular Genetics, Future Food Beacon), Dr Scott Young (Environmental Science), Prof Debbie Sparkes (Agronomy), and Prof Paul Wilson (Agricultural Economics). The project will work with partners in Indonesia (including colleagues from the Catholic University of Delasalle working in agriculture, and Manado State University, working in biology), looking for solutions from the ground up, and contributes to the delivery of Indonesia's Food Security Research Policy (2016-2019).

Reach and Teach Science in Africa: Strengthening research capacity for generating future foods

By Ute Voß and Thomas Alcock

In April 2019, Nottingham Research Fellow Dr Ute Voß and Doctoral Prize Fellow Dr Thomas Alcock received funding through the Future Food Beacon Partnership Fund to travel to Benin, West Africa. In this article, they offer insights into their experiences teaching molecular biology and crop breeding principles to 100 Africa-based researchers as part of the 'Reach and Teach Science in Africa' program developed by the JR Biotek Foundation.

It was in Paris airport during a stopover on the way to Benin that we first met with Carol Ibe, founder of the JR Biotek Foundation, and the rest of the Reach and Teach Science in Africa team. There was a brief moment of panic when it didn't look like we would all make it onto our next flight. To our relief, everything went well in the end, and all of us, along with lab coats, pipettes (thanks Darren Hepworth for the loan!), notebooks, programs, workshop bags, and all consumables required for 4 days' worth of lab practicals, made it safely to Cotonou, the largest city in Benin.

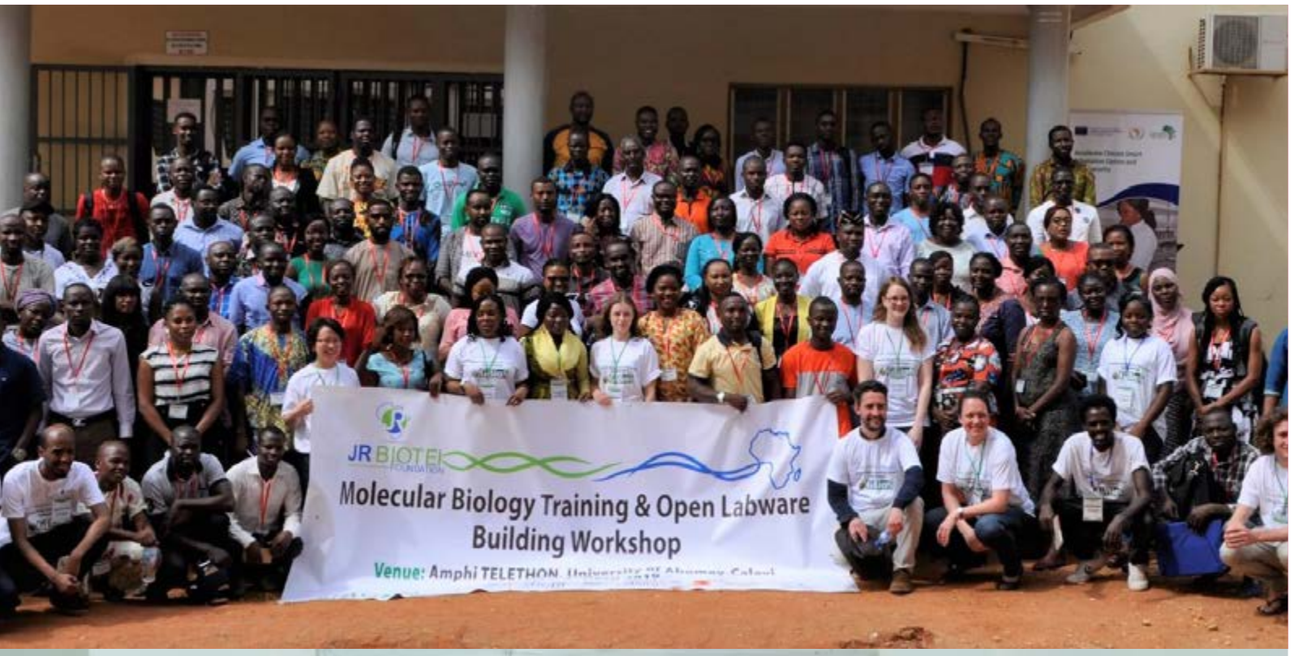
It didn't take long after landing for us to realise just how hot and humid this tropical country is. Fortunately, our host, Dr Enoch G. Achigan-Dako, head of GBioS at the University of Abomey-Calavi was far more hospitable, greeting us with a tour of his excellent research facilities, followed by sampling of various bissap fruit, moringa and lemongrass teas, produced by his very own research team. We took some time to sort arrangements for the following week, and to familiarise ourselves with the lab space and the programme, before kicking off the workshop the following morning.

Day one of the workshop, largely funded by the University of Cambridge, commenced with a warm welcome from Dr Enoch to all 100 of the workshop participants. He spoke of the need for increased capacity strengthening in Africa, and expressed gratitude to the JR Biotek Foundation for hosting the workshop in his department. This was followed by further welcomes from Carol Ibe, and workshop organiser Jennifer McGaley (PhD Student; University of Cambridge), and the workshop was officially opened.

Following these friendly introductions, the teaching activities began. Days one to three comprised lectures given by most members of the Reach and Teach team covering molecular biology, crop breeding, and a statistics session run by Catherine Danmaigona Clement (PhD student, Texas A&M University and JR Biotek Foundation's first training alumna). Ute gave lectures on cell biology, transcription and translation, and recombinant DNA technology, and Thomas covered conventional and marker-assisted breeding technologies and plant nutrition. Dr Enoch also gave a lecture covering ongoing work at the University of Abomey-Calavi which largely focussed on improving resources available for various 'orphan crops'. Three species that his group are particularly interested in are Miracle Berry, a fruit producing plant that causes sour flavours to be perceived as sweet when consumed; Cleome, a vegetable crop with potential for elevated vitamin A & C varieties to be produced; and Kersting's Groundnut, a crop of high economic importance for farmers in West Africa.

Towards the end of each day, the applicants were split into groups, with some members taking part in hands-on molecular lab training while others formed teams to develop a strategy for JR Biotek's Bio-Innovation Pitching Challenge, in which they developed ideas for start-ups or non-profit organisations within the theme of biotechnology. We were involved with the lab training, in which participants were instructed in the use of pipettes, through to DNA extraction and polymerase-chain reaction (PCR) setup. Splitting into these smaller groups was a great way to engage with participants on a much more personal level. Rather unexpectedly, this led to a fascinating discussion between ourselves and members of different African nations on the best ways to solve the hunger crisis! Though no definite consensus arose, it became clear that whilst a complex issue, there are strategies that can be implemented throughout the food supply chain to increase crop yields, and subsequently get this produce to those who need it most.

Days four and five followed a different structure, including a training session on how to build a basic, computer-based microscope run by Dr Fernan Federici of the Pontificia Universidad Católica in Chile, and a professional development workshop run by Dr Matias



Acosta (Feodor Lynen Fellow, University of Cambridge). The workshop ended with the Pitching Challenge presentations. During this session, some major themes surrounding challenges in African food production emerged, including issues of communication between researchers, politicians and food producers. As one group strikingly put, there are over 2,400 papers published concerning smallholder farmers. However, the farmers who could benefit most from this information have little to no access to this information. Increased use of smartphones in this region over the last few years has presented a new opportunity: developing apps to enable this information to reach smallholder farmers. Whilst it may take a while for this to be fully realised, this was a great idea that could contribute to greater knowledge sharing in future. Following an unexpectedly emotional closing session to the workshop, featuring an award ceremony for winners of the Pitching Challenge, and the handing-out of certificates to all participants, we said our goodbyes and headed back to our hotel.

The following day, the teaching team travelled to Ouidah, a town to the West of Cotonou, where we were taught a little about the dark history of slavery in the region. Between the years 1600 and 1900, it is estimated that over 11 million slaves were transported from West Africa to the Americas, many of these from Benin. Learning about these atrocities in one of the most directly affected regions, and seeing the harsh conditions that slaves were exposed to, added a new layer of sorrow to our feelings surrounding these terrible practices.

That evening, the team from the University of Cambridge headed back home. However, we had decided to stay in Benin for a few more days in order to get a feel for local cultures and agricultural practices. Dr Enoch arranged a three day tour around the country for us, starting with a visit to the National Institute of Agricultural Research in Benin (INRAB), where we discussed breeding priorities in the region and potential avenues for future collaboration. We then headed to Grand-Popo on the coast to see some local vegetable farms. These focussed on growing carrots and African eggplant, and were well-organised, using irrigation and chemical inputs, as well as providing employment to people living in the area.

We then travelled North, into the heart of the country, where most of the population relies on smallholder farming for subsistence and a meagre income. We met with Nestor and his family in a small community living in mud houses near to Dasso. Around 20% of their produce was maize, for personal consumption. The remaining 80% was the West African crop known as Kersting's groundnut. This has significant economic importance to farmers, its value driven up by its use as a food during festival periods. By selling this crop at local markets, Nestor is able to buy other foods to supplement his family's diet. This community faces several challenges though. Principally, longer term storage of crop produce is an issue as proper storage facilities are not available. With harvest only twice a year, this can seriously affect profits and food security. Further issues include lack of access to manual labour in the preparation for sowing of seeds. Whilst land is frequently available for planting, without access to farming machines, this often goes unused. Similarly, whilst suitable groundwater is available, this must be taken from deep underground, which we learned first-hand is a labour intensive process! Any challenges that this community faces are only exaggerated by utilising seed from last year's harvest for the following season's planting. This is due to economic insecurity, which leaves farmers unable to afford new seed when it is needed. Without buying new seed each year, optimal yields cannot be achieved, and this causes a vicious circle of lower harvest resulting in sustained poverty.

As plant scientists we are often confronted with statements concerning food insecurity, growing global populations, rural farming practices in developing nations, and the lack of knowledge transfer between researchers and food producers. During our visit to Benin, these issues suddenly became a lot more real to us. During the week of the workshop, we met with 100 young African researchers from 19 sub-Saharan African countries and heard 100 stories about the struggles of science teaching and research on this continent. Common complaints were lack of funding, lack of access to labs, and lack of supervision or expertise available. At the same time, we saw enthusiasm for their work and hope that this might one day improve the lives of African farmers. In the few days following the workshop, we then witnessed the reality of smallholder faming in impoverished communities. It became clear that a variety of approaches ranging from improved infrastructure, education, and policy changes are required to improve living conditions in this region. Agricultural research will certainly also play a role in achieving this goal, highlighting the importance of continued support for work in this area.

Global-local knowledge systems for innovation and entrepreneurship in the developing world: An international workshop in Nottingham, 2-3 May 2019

By Bin Wu and Peter Noy

About 2 billion people (two thirds of the population) in the developing world live on about 500 million small farms, defined as plots of land smaller than 2 hectares. Smallholder farmers are “knowledge-rich, but economically poor” and there is a significant gap in understanding how local knowledge might shape innovation.

As a result, smallholder farmers are often excluded from the current system of knowledge exchange, leading to missing or inadequate contributions of local knowledge in many global research and development projects. Dr Bin Wu, in collaboration with the Future Food Beacon, Haydn Green Institute for Innovation and Entrepreneurship (HGI) and the African Diaspora Academic Network – UK (ADAN-UK), put together an international workshop for communication, interaction and cooperation between grassroots innovators and researchers/professionals/change agents, with the vision of starting to address this knowledge gap.

The event was attended by more than 50 people from a wide range of backgrounds, including international participation of eight invited speakers from five countries (China, Bangladesh, Ethiopia, Kenya and Zimbabwe); engagement with African diasporas from both academia (5 delegates from ADAN-UK) and local communities in Nottingham; other stakeholders from across the sector (universities, government and non-government agencies) and across disciplinary boundaries (agriculture, economics, education, sociology, political and management sciences); and participation and contribution from some of the fantastic student entrepreneurs at UoN, who have been working in Africa as part of their training and development.

Early on the first day of the workshop there was a buzz in the room. The international guests had arrived and with them they brought excitement and energy. There were some reunions, but most of the interactions were new ones and a sense of discovery was tangible. The main objectives of the workshop were to address two questions: 1) What are the innovation challenges and opportunities for smallholder farmers? 2) How can a global university like UoN work together with multiple stakeholders to support local innovation and entrepreneurship to empower smallholder farmers? The first session kicked off with introductions from the organising parties, highlighting the contribution that Nottingham can provide to food security research and international collaboration. Nothing could stop the continued conversations and networking that began immediately, even the taking of photographs!
Over the course of the first day attendees heard incredible stories of smallholder farmers across the globe, from Bangladesh to China to Ethiopia to Zimbabwe. Each speaker exuded passion through their stories and brought with them key challenges that each setting faces (for example, female empowerment, cooperative initiatives, poor infrastructure). Just before lunch the room was really lit up by Florence Mtambanengwe, who spoke of Farmer Learning Centres that she has been involved in setting up in Zimbabwe. These organisations provide local farmers with a place to go to learn about the science behind farming, exchange knowledge and experiment with new technologies. This concept really grabbed the audience and they were full of questions.

The afternoon session brought about the first opportunity for group discussions and the groups sought to define their key challenges for smallholder farmers. Working in groups of about 8, there were wide-ranging discussions covering market exploitation, political establishments, value of goods, the climate crisis, post-harvest processing and losses, in-country infrastructure, hunger, technology adoption, knowledge exchange and education. The challenges facing smallholder farmers are vast but their conversations were positive: What progress can we make? How can we help to change these problems? What good experiences can we share? How can we support entrepreneurship and innovation in smallholder farmer communities?

The second day arrived, and things picked up from day one. Attendees heard about an NGO-led training course for rural entrepreneurs in China, university engagement for entrepreneurship in coastal Kenya, and diaspora links for agricultural innovation in home communities in Africa. One of the highlights of the second day were two HGI supported student entrepreneur projects in rural Africa which have won top awards at national (UK Enactus Competition) or university (VC Award in Ingenuity 19 Competition) levels. In particular, Tabitha Wacera told her story, from being a girl in Kenya who had to fetch water every day to starting a business that provides sustainable water for Kenyan communities through solar-based water pumps. This story resonated with many in the room and really demonstrated the change this generation can make. The buzz continued and the delegates assembled back into groups to discuss actions to build upon for future activities. By the end of the event there was a real feeling of opportunity, and that the start of solutions were just being born.

We would like to thank all delegates and in particular those invited speakers and ADAN-UK members, who made the event so successful. Hopefully this can initiate a “triangular relationship” between global universities (UoN), local community groups (African Diasporas) and international partners via staff and students’ community engagement on sustainable development goals in general, and sustainable agricultural innovation and food security in particular.

AfriPlantSci 2019 Healthy Plants, Healthy People, Healthy Planet: Building African capacity to tackle African plant health challenges in Africa

By Silvia Busoms and Levi Yant

Recently we organised and taught the AfriPlantSci 2019 initiative, which aimed to increase capacity in plant science across Africa through training, technology transfer, and network development. One motivation was to enable an African voice to be present in global scientific discourse. A second was to engender the capacity to do the top plant science in the world in Africa, by Africans. These are big goals, but it's impossible to affect change without such aspirations. AfriPlantSci 2019 was supported by the The Alliance for Accelerated Crop Improvement in Africa, John Innes Centre, and Pwani University.

Upon the initial call for the course, the response from interested African researchers was immense: an astonishing 620 applicants sought the 23 positions. The outstanding participants we eventually did enrol came from 8 African countries and highly diverse backgrounds (including agronomists, molecular biologists, pathologists, biochemists and biotechnologists). This underscores the desire among African scientists to engage with academics around the world to build meaningful links and participate in advanced training. We held the 2019 workshop at Pwani University (Kilifi, Kenya), with the beautiful backdrop of the Indian Ocean. Sessions focused on a wide range of topics: from building 'soft' skills such as enhancing collaboration and grant writing, to genome and pest bioinformatics, to laboratory fundamentals, golden gate cloning, and abiotic stress theory and experimental practice. To accompany the lab sessions, participants were taught about related cutting edge research advancements and the theory behind them from invited guest lecturers and group leaders. These lectures were open to the wider Pwani University student body and generated a lot of interest across faculties at the University. It was truly inspiring to see such excitement for plant and molecular biology-related research across campus.

The revolution in plant genomics has opened up new perspectives and opportunities for plant breeders who can now apply molecular markers to assess and

enhance diversity in their germplasm collections, to introgress valuable traits from new sources, and to identify genes that control key traits. However, it is the duty of universities and scientists from public and private-sectors to improve dialogue with plant breeders. Many of the participants are members of local institutions of agricultural research and they are determined to improve rural development and eradicate food insecurity and poverty of farmers.

At the AfriPlantSci workshop we aimed to provide new incentives, knowledge and funding mechanisms that promote the translation of new innovations in plant science into concrete benefits for farmers, enhancing the links and communication skills of the participants. Participants were clear from the outset about their research priorities and we could therefore tailor our teaching to their interests. Coming from directly affected countries, the impact of global climate change on crop production was a major and increasing concern for all. They are already affected by ongoing temperature increases and changes in precipitation resulting in increased drought, leaching of soil nutrients, increased soil salinization, and reductions in water availability. Thus, in our sessions we focussed on ways to understand and translate the strategies adopted by plants against abiotic stresses and the common "omic" approaches used in plant stress research, bringing evolutionary biology and physiology toward applications in crop improvement. This included hands-on sessions in detailed soil environment characterization, plant stress tolerance physiology, and local adaptation testing. Most of the participants were interested in African crops affected by these problems and we consistently had engaging discussions that brought the theoretical and lab-based science alive and into the real world.

From our side, we feel that this 2-week workshop was a tremendous success. We believe that participants, facilitators and organisers will benefit a lot from the course. It was hugely fulfilling to meet, network and form potential future collaborations with participants, all of whom were so talented, enthusiastic and passionate about using plant science to improve livelihoods. The chance to teach and work with such enthusiastic researchers and students was a privilege and it was obvious that we interacted with future leaders of African plant science.

We are in the process of organising another course in 2020, led by the University of Nottingham. Interested parties are encouraged to reach out to either of us: Sylvia.busoms@nottingham.ac.uk or levi.yant@nottingham.ac.uk. We found AfriPlantSci 2019 a hugely rewarding experience and we encourage other individuals and institutions to participate in AfriPlantSci 2020 with us!

Reflections on public engagement

The Nottingham Festival of Science and Curiosity

By Lexi Earl

The Future Food Beacon participated in the Nottingham Festival of Science and Curiosity in February 2019. The Festival (FOSAC for short) is a yearly celebration of all things science, in and around the city. The main festival day is the Saturday, and there are also activities taking place in schools the week before, and in libraries the week after. This year, we took two activities to the Saturday festival. We were based in Central Library, right in the heart of the city, and our two tables were located amongst other research groups from the University of Nottingham.

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One of our activities showcased our LEGO sequencer. This contraption is a LEGO version of a DNA sequencer, like that used by our scientists in their labs to read DNA sequences of individuals – be it plants, people or anything really – which gives us insight into how individuals differ from each other. In Future Food we use this in many ways, such as sequencing varieties of plants that prosper under different conditions to predict how their offspring might perform; finding the DNA sequence of our herd animals to drive breeding programs; or sequencing the soil itself to discover what microbes are present in it that we never knew about and how those microbes help plants to grow!

The multicoloured LEGO units are pulled through the sequencer, which we can show on a computer screen as it happens. The units are then decoded by the computer to form a word, in this case, hello! We had many young people come by to try out the sequencer.

We also brought one of our new activities to both the event on Saturday, and the events that happened in libraries over half term. This activity is called Food Tales! Food Tales encourages young people to write or draw stories, using food as a medium to do so. Food experiences define and shape our lives, and we are interested in how we might get young people to explore their own lives through their food experiences. Developing vocabulary around food is important because language allows us to express thoughts, feelings, desires, and choices. The more we know about food, the more we need to be able to express our knowledge.

Food Tales provides pens, coloured pencils and post-it notes and asks young people: 'can you tell me a story about food?' This story can be fictional or real, can be drawn, written or told verbally. At Meadows Library, we also had some kitchen objects from the library's play kitchen. This included plastic pots, plates, cups, tea pots, and food stuffs. We had herbs from an allotment and kitchen whisks and wooden spoons. Stories were often told verbally as young people were drawing or writing, or, in the case of very young children, were created through the objects we had. For example, the picture below is of one story about cake, rosemary and strawberries, all mixed together.

Other stories were about how disgusting something was, or the people children ate lunch with. Oftentimes the stories and drawings were about favourite foods (pepperoni pizza seems to be a universal winner).

We loved being able to interact with the local communities, talking to them about their lives and food stories! We will certainly be back for this festival next year!

Why should academics engage with the public?

By Sina Fischer and Michael Wilson

March was a busy month for Future Food Beacon researchers Dr Sina Fischer and Dr Michael Wilson as they participated in Science in the Park and Family Discovery Day. Here, they recall their experiences, and explain why they participate in these types of public engagement activities.

Sina

In March Michael Wilson and I teamed up with our colleagues to take part in different public engagement events. We had prepared ourselves for busy days, engaging with children and their families, explaining science and showing them what our research is all about.

Both outreach days were a tremendous success. We were unbelievably busy. At the activity "What makes plants grow?" we showed close to 200 children how a researcher sets up an experiment to understand how the environment affects plant growth. The children were eager to participate and to set up their own experiments. We gave them each 6 small pots and they padded them with cotton wool which we were using instead of soil to allow the plants to root. (This method is used in schools too, to grow beans in cups on windowsills!) After watering their pots using pipettes, the children were able to choose between different seeds we provided for them.

In order to provide the children some visual idea of what to expect, we grew a number of different plant seedlings. Some we put under stress conditions (like not watering) for a few days before the event, in order to illustrate how plants respond to their environments. We showed the children a papaya fruit, how to extract the seeds and what a papaya seedling would look like in a few weeks' time. We also brought in some peppers from the supermarket from which we had grown pepper plants in preparation.

The favourite, however, was the fast growing buckwheat. With its unusual, triangular seeds and very pretty white flowers these plants attracted the most curiosity from the children and many chose to use them for their experiment. After placing some seeds into each pot they then chose different treatments. For example, by adding salt or healthier, low-sodium salt to one pot each, they would be able to see if plants also benefited from a low sodium diet like humans. This mimics the types of experiments we conduct in our labs. Each step in their experiment was meticulously documented by the children in a professional spreadsheet that we brought for them. Here they were able to note the layout of their experiment and make observations about when plants would germinate and how well they would grow. They were able to take their experiment home to observe the results.

Overall, I thought the events were a tremendous success. I enjoyed engaging with people about my research and showing children how fascinating plants are. As a scientist I am constantly working on gaining knowledge which can help to improve the quality of human food or to improve yield. Much of my work however takes decades to translate into anything that benefits the general public. Engagement events like this enable me to immediately give something back to ordinary people. I also aspire to become a role model for children interested in becoming researchers themselves. I would love to stimulate interest in plants or science in general and am always happy to answer any questions on how to become a researcher. My ultimate goal would be to have helped someone in their decision to follow an education into science and become a researcher themselves!

Michael

In the main hall at Science in the Park we had the Lego Sequencer, a Lego model of a nanopore sequencer of the kind we use to sequence the DNA of organisms. Sequencing DNA allows us to find out what makes organisms both unique and similar. Inside our Lego Sequencer were a Raspberry Pi, some sensors and a motor. Children had a sheet of plant properties – size, colour, bushiness – and a code of coloured beads to represent those particular properties. Children could assemble a 'DNA sequence' of those magnetic coloured beads, then offer them up to the sequencer, which would pull them through, read the colours and display this on the screen with what it thought the plant would look like. Children can then compare the computer version to their drawing of what they thought it would look like. This activity, being right by the main doors of Wollaton Hall was incredibly busy – we lost count at 500 children and at peak time the table was crowded with families 3 deep listening enrapt to our principal volunteer explaining DNA and sequencing to them.

This was a learning experience for me as much as the children! Don't forget the power supply for a computer and monitor was the first lesson, or you'll start late. Talking all day to hundreds of people is tiring and all-consuming – I don't recall eating lunch; being sustained by coffee and chocolate eggs. Taking what we do in the rarefied atmosphere of academia and tuning it for ages 3 upwards is hard! The people we talk to day-in-day-out are so well versed in what we do that stepping back and describing what DNA is, rather than some of its more esoteric characteristics, is much harder than it sounds! People who can master that have an incredible skill. This brings me to the most important lesson I learnt. Find someone who can do that! I lucked out by being given Dr Leora Hadas, from the Department of Cultural, Media and Visual Studies, who was awesome in rapidly understanding the sequencer, having seen it for the first time on the day, and getting a series of talking points together that were pitched perfectly at the audience in front of her. And I learnt to be flexible – different people got different things out of the experience. Some had no idea about DNA and sequences, and I like to think they went away with some insight into DNA, whereas others arrived having been taught about DNA already, and I hope that they went away with a better insight into what we do in the lab.

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