



University of  
**Nottingham**  
Future Food

# Exploring new ways to feed the world

**Future Food**  
Beacon of Excellence





Research Fellow Grace Kangara applying foliar fertiliser to improve crop nutrition

# Contents

**Director's update**

04

**Overview**

06

**Snapshot of achievements**

08

**Case study one:  
The National Food Strategy**

10

**Case study two:  
Our Nottingham Research Fellows**

14

**Case study three:  
Launching our technology platforms**

18

**Case study four:  
Project updates**

26

**Beacon leadership team**

32

**Beacon staff team**

34

The University of Nottingham has over 250 researchers working on solutions to challenges across the food system

AEDNA  
researchers

## Director's update

It has been another bumper year for the Future Food Beacon. Despite the continued challenges of Covid-19, Beacon researchers have successfully made progress on projects, grants, and publications. We are now in the fifth year of the life of the Beacon, and are starting to look ahead to the future.

The Future Food Beacon is an open research cluster exploring ways to feed a growing population sustainably within a changing environment. The University of Nottingham has over 250 researchers working on solutions to challenges across the food system, and the Future Food Beacon focuses the breadth and depth of this expertise to generate transdisciplinary solutions to deliver sustainable and equitable access to healthy foods.

Our research themes illustrate the breadth of expertise available at Nottingham:

- Future proofing agricultural systems
- Food for sustainable livelihoods
- Food for health
- Smart manufacturing for food

Our commitment to talent development has seen our Nottingham Research Fellows transitioning to Faculty positions, with all researchers now part of the Schools of Biosciences and Computer Science. Five new international scholars joined the Future Food Beacon in October 2021 as part of the joint UoN-Rothamsted International Agriculture DTP. Our group leaders are building their research groups by attracting excellent postdoctoral researchers and PhD candidates.

Future Food Beacon successes have continued to grow, with 9 awarded grants worth £1.8 million in 2020/21, and 72 papers published.

Food poverty, already a known issue across the UK, grew through the series of lockdowns and resulting job instability

A social eating canteen in Brazil

## Overview

As we move into a world living with the threat of Covid-19, the imperative for food systems change has never been more urgent. Covid-19 laid bare the failures of the current food system, designed for just-in-time supermarket chains and large corporations to profit, with little concern for the environmental impact of the system, nor the people exploited by the way the system is constructed.

Problems with supply chains at the start of the pandemic meant people had to look elsewhere for supplies, including local grocery stores, food cooperatives, and community eating schemes. Food poverty, already a known issue across the UK, grew through the series of lockdowns and resulting job instability. Marcus Rashford's campaign for holiday meals is just one example of hard-won benefits to support working families. Combined with the impact of Brexit (lack of haulage drivers, disputes over exports and imports), the opportunity for systems change couldn't be timelier.

The publication of the National Food Strategy (for England) was therefore well received and extremely necessary. The report sets out four areas of focus to transform English food systems, including: breaking the junk food cycle; reducing diet-related inequality; making the best use of the land; and creating a long-term shift in our food culture. The Future Food Beacon contributed to the report and we detail our involvement with the report in Case Study One.

As we work out how to live with Covid-19, the Future Food Beacon is focused on creating interdisciplinary solutions to the new challenges for food and nutritional security we face. Established in 2017, the Future Food Beacon is a model for how researchers, producers, consumers and governments can work together to achieve secure, healthy and sustainable food systems by 2050. Our experts work in the fields of genome-enabled plant and animal sciences, cutting-edge nutrition science, food processing and manufacturing, and digital technologies. We explore the economics, legal, social, cultural, historic and ethical issues that underpin and shape food systems.

# Snapshot of achievements

Supported submission of

**230**

Beacon related grants (£134m)

**151**

papers published since July 2017 (Beacon researchers only)

**400+**

stakeholders from academia, business, civil society and government

**4**

technologists

**£2.9m**

spent on 31 items of equipment

**29**

Innovation Fund proposals awarded (£549k)

**118**

supported grants awarded (£22.4m)

**57**

papers published 2020/21 (Beacon researchers only)

**2**

senior group leaders

**15**

PhDs in the International Agriculture Doctoral Training Programme (further 5 to commence in 2021)

**£0.4m**

committed for new facilities (ÆDNA)

**6**

projects partnering with EMBRAPA (Brazilian Agricultural Research Corporation) (£124k)

**56**

grants awarded to Beacon researchers (£14.1m)

**6**

Nottingham Research Fellows

**7**

doctoral prizes awarded (£168k)

**12**

Innovation Challenge PhDs (2 based at our Malaysia campus)

**6**

Future Food Fellows awarded

**18**

partnership proposals funded (£133k)

**18**

grants awaiting outcome (£12.4m)

**7**

post-doctoral researchers

# Case study one: The National Food Strategy

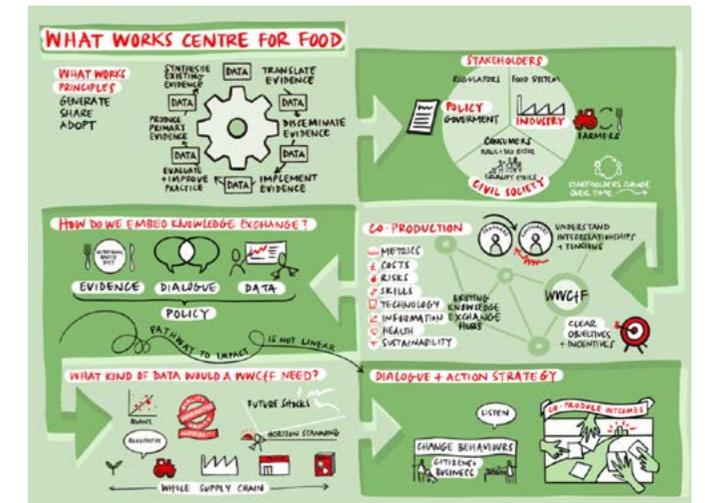
Government procurement can play a role in healthy diets

The National Food Strategy is a sweeping document covering most aspects of the English food system. It focuses on two main problems: addressing the junk food cycle, and the invisibility of nature. The Future Food Beacon was engaged in the development of the strategy in several key areas including a What Works Centre for food, concerns for food inequality and access, and procurement practices.

## A What Works Centre for food

As part of *Recommendation 11 – Invest £1 billion in innovation to create a better food system* – the NFS recommends the creation of two What Works Centres for food, one on farming (already being piloted by AHDB) and one based on dietary change, with FSA leading Whitehall thinking. The Future Food Beacon has been instrumental in drawing attention to the need for a food systems innovation hub, which we have raised with both Melanie Welham (Executive Chair BBSRC), Guy Poppy (Programme Director of the Strategic Priorities Fund Food Systems programme at UKRI) and Henry Dimbleby (National Food Strategy). Such a hub would combine researchers, business, and civil society to think ambitiously about how to secure sustainable and healthy food for all.

A What Works Centre for food builds on the idea of an innovation hub and will provide various tools to develop, implement and evaluate policies, practices and standards to help shift the UK towards a healthier, more sustainable diet. Such a diet would include fewer highly processed foods high in salt, fat, and sugar, and more plant-based foods, including fruits and vegetables, wholegrains, and plant-based proteins.



This would align with Defra policies for environmental sustainability and the UK Eatwell strategy for healthy diets. We must align UK production and imports to this diet in a way that is socially acceptable, economically viable and environmentally sustainable. A key part of the What Works Centre will be its ability to connect thinkers and practitioners in academia, industry, civil society, and government with the goal of ensuring full integration across the food system from producers to consumers to ensure system changes do not have unintended consequences. We ran two workshops with stakeholders from all sectors of the food system to develop ideas of how a What Works Centre for food will be organised, its remit, the data it would review, and its main purpose. The goal is to develop the blue print of a What Works Centre for food with transferable protocols, methods and insights that would be useful to a wide range of future delivery models.

## Government procurement

Food procurement by government is big business, as the government provides food in schools, hospitals, prisons and the armed forces, to name a few. As part of *Recommendation 13 – Strengthen government procurement rules to ensure that taxpayer money is spent on healthy and sustainable food* – the NFS recommends government purchases food for schools that is healthy and sustainable. Models of this type of purchasing are necessary. The Future Food Beacon provided such an example as part of the consultation on the National Food Strategy through the work of our 2018-2020 International Visiting Senior Research Fellow, Dr Tereza Campello. Dr Campello was the Minister of Social Development and Fight against Hunger from 2011-2016 in the Brazilian government. As Minister she led changing public procurement for schools in Brazil, who serve meals for free to some of the 43 million children who attend school. Dr Campello worked in her role as a Minister in the Brazilian federal government to create a legislative framework mandating that 30% of food bought for school meals had to come from small, local farmers.

Within the scheme, guidance on the menu accounts for local production, seasonality, and percentage of fruit and vegetables. The program is also linked to the provision of food and nutritional education to encourage changes in eating habits towards healthy foods. The National School Feeding Program (PNAE) that Minister Campello created now reaches 40 million students, and accounts for 1.2 million tons of food. PNAE also has the advantage of promoting food security, and sustainable and healthy production, strengthening small local producers and boosting local economies. Such a system could be implemented in the UK, benefitting both our farmers and our children.

## Access to healthy foods

Understanding the food environments of different places (home/school/work) and the ways people shop for food, are crucial if we are going to bring about dietary change on a national scale. People on lower incomes are more likely to live in areas termed 'food deserts', where obtaining healthy foods, and particularly fresh foods and vegetables, are difficult. We have ongoing projects using modelling approaches of individual food purchase and consumption patterns, based on real world food provision networks to forecast dynamic changes in food insecurity in the UK. This work is being undertaken by colleagues in Mathematics, the Business School, and N/LAB.



Understanding access to different food environments is crucial

# Case study two: Our Nottingham Research Fellows



The Future Food Beacon is committed to talent development, and our Nottingham Research Fellows provide fine examples of how this can be done. Four fellows, Drs Gabriel Castrillo, Guillermina Menciondo, Sally Eldeghaidy and Michael Pound have already transitioned into the Schools of Biosciences (Castrillo, Menciondo, Eldeghaidy) and Computer Science (Pound). Our other two fellows, Dr Rahul Bhosale and Dr Sina Fischer are still completing their fellowships but have secured their transitions to the School of Biosciences in December 2021 and April 2022 respectively.

**Sally Eldeghaidy's** research focuses on imaging the human brain, particularly related to gastrointestinal function (gut-brain axis), and food perception, using magnetic resonance imaging (MRI) techniques. Sally is leading a collaboration with Wageningen University, funded by the Royal Society, to develop MRI methodologies to enable protein digestion in humans to be measured for the first time non-invasively in the body and to simultaneously assess associated gut-brain interactions. These techniques will allow researchers to assess the digestion of different sources of protein, including plant and animal protein, supporting the demand for alternative proteins. Sally has also been funded by the Precision Imaging Beacon to develop brain imaging techniques to study the relationship between vascular barrier permeability of the gut and the brain in patients with inflammatory bowel disease. This will allow her to study the effects of food/diet modulating gut permeability, and the impact on gut-microbiota-brain interactions. Sally has published in *Critical Reviews in Food*

*Science and Nutrition* on umami perception, and in Physiology & Behaviour on the effect of thermal taster phenotype on brain sweetness perception.

**Rahul Bhosale's** research concentrates on root anatomical traits that enable plants to acquire more resources from the soil without compromising metabolic investment. He has been building his success as a co-investigator, to supplement his BBSRC fellowship. He has been part of successful BBSRC sLOLA and EU Horizon 2020 grants, worth <£10million. Rahul is supervising six PhD candidates, and has one postdoctoral research assistant. He has published papers in *Science*, *PLoS ONE*, and *The Plant Journal*.

**Guillermina Menciondo's** research has focused on understanding the molecular and genetic components regulating plant-environment interactions, and particularly wants to define the biochemistry of how plants sense environmental change, and to identify promising targets that can be manipulated in agriculturally important crops. She has been funded by industry (AB InBev and REZATEC); Research England GCRF, two BBSRC awards (iCASE BBSRC), the Newton Fund, EU Horizon 2020 and she is a Co-I in a BBSRC CTP bid recently awarded with the International Barley Hub (James Hutton Institute) and industry. She has been actively working to establish an international network through projects awarded and projects in development. She has established collaborations with colleagues in South Africa, Zimbabwe, Australia, Argentina, Brazil, USA, Malaysia and Indonesia. She has supervised five PhD students and has one postdoctoral research assistant.

**Gabriel Castrillo** has been promoted to Associate Professor within the School of Biosciences. Gabriel has been focused on research revealing the molecular mechanisms behind the role of the root microbiome in mineral nutrient homeostasis in plants. He has published papers in *Nature*, *Science*, *Current Biology* and *Nature Communications*, amongst others. He has won a BBSRC-NSF grant for research into plant-soil microbiome interactions.

This joint project with the University of Kansas, investigates how plants and microbes adapt to a shared environmental stressor, in this case, drought. Gabriel has also been funded by The Leverhulme Trust to investigate how microbes affect root system architecture, and by the Royal Society, researching how carbon accumulates in the plant root.

**Sina Fischer** researches whole genome duplication in *Arabidopsis thaliana*. She has published work on leaf potassium homeostasis in neo-tetraploids, defining a gene network that changes in expression in response to whole genome duplication. Based on this work, Sina submitted a BBSRC responsive mode grant. She has continued to work on a Royal Society-funded grant investigating ten ABA-signalling genes, which are induced in neo-tetraploid roots. As part of this work, Sina has established a collaboration with researchers in Wageningen. Sina was successful in having a project accepted to exhibit at the Royal Society Summer Science festival in July 2022. Sina has published in the *Journal of Experimental Botany*.

**Michael Pound** has been funded by BBSRC for his work on AI and image analysis for plant phenotyping. The project trains deep computational networks to capture expert gaze information during repetitive tasks such as disease scoring of crops. Incorporating gaze information allows the deep networks to train faster, and achieve higher accuracy. Once any network has been trained, it no longer requires a human gaze to follow, allowing it to identify key areas of an image itself, and predict the disease score on new data. Mike has also developed a multi-resolution approach to analyse X-ray Computer Tomography (CT) images of roots growing in soil environments, and has secured funding from PhenomUK to run a pilot study on using networks to predict future growth rates. Mike has published in *Remote Sensing*, *GigaScience*, and *IEEE Transactions on Image Processing*.



Cocoa trees on a farm in Colombia. Our cocoa project is being exhibited at the Royal Society 2022.



## Case study three: Launching our technology platforms

Ancient and  
Environmental  
DNA laboratory

The Future Food Beacon has invested in a number of technology platforms to boost capability and capacity at Nottingham. These technology platforms are composed of key instrumentation and are led or supported by a Beacon staff member.

### Genomics platform: Deep Seq

The Future Food Beacon invested in numerous items of equipment to increase the sequencing capacity and capability of Deep Seq. New equipment has included the Nanopore GridION X5, the 10X Chromium Controller, the TTP Labtech Mosquito HV Robot, the Bionano Saphyr, and the development of a novel portable field kit for in-field sequencing. This equipment has proved especially fruitful during Covid-19, as Deep Seq became part of the Covid-19 Genomics UK Consortium (COG-UK), sequencing 10,000 viral genomes, which have been used to identify patterns of transmission and emergence of variants at a local, national, and global level. Future Food Beacon technologist, Dr Christopher Moore, has been a core member of the team undertaking this work, and has been using the GridION to run samples. The team at Deep Seq have recently been awarded the Vice Chancellor's medal for their contribution to the fight against Covid-19. Chris will now be working on a Covid-19 waste water monitoring project, sequencing waste water in an attempt to monitor Covid infections across the population.

As well as working on Covid-19 sequencing, Chris has also delivered multiple sequencing projects for the Beacon. These have included using the Mosquito HV robot for high throughput sequencing of 300 lines of foxtail millet, an important crop in semi-arid regions of East Asia. This data set will be used in a genome wide association study (GWAS) to identify how crop traits are influenced by their underlying genetic makeup. Chris has also sequenced the genome of moth bean, a drought resistant crop commonly grown in India. This sequencing was carried out on the GridION and Illumina NextSeq and has provided data that can be used to help understand the moth bean's drought tolerance and to improve it as a crop for use in other arid regions of the world. The Future Food equipment investment has also enabled industrial collaborations including one with a commercial seed grower to sequence the genome of one of their F1 hybrid lines and two parental lines of parsnip using Oxford Nanopore, Illumina and Bionano Saphyr technologies.

The development of the in-field sequencing kit has allowed researchers to perform sequencing in the field, rather than the lab. The kit is equipped with all the instruments necessary to process a sample and sequence it with limited access to power or lab facilities, all contained in a compact suitcase. This was put to the test by researchers on our project examining cocoa fermentation. On-farm DNA sequencing of microbes involved in fermenting the cocoa beans was conducted on remote farms in Colombia, proving that the technology could be used to monitor cocoa fermentations on farms in real time.

## ÆDNA: Ancient and Environmental DNA laboratory

We are very pleased that the ÆDNA (pronounced Edna) lab is under construction at our Sutton Bonington campus. The first of its kind at the University of Nottingham, and the only facility in the East Midlands, ÆDNA will allow the isolation and analysis of damaged, degraded and low-copy DNA to address research questions across disciplines. The laboratory will be open to anyone at the University and beyond, and has been co-financed with the support of the Department of Classics & Archaeology, the School of Geography, and the Life in Changing Environments Interdisciplinary Research Centre, as well as the Future Food Beacon.



Lead by Dr Andrew Clarke, the new laboratory will be a dedicated, high-specification facility. To avoid contamination and for publication, it is necessary for ancient DNA to be extracted in a dedicated facility built to recognised standards.



The ÆDNA lab provides a sterile environment to process DNA samples.

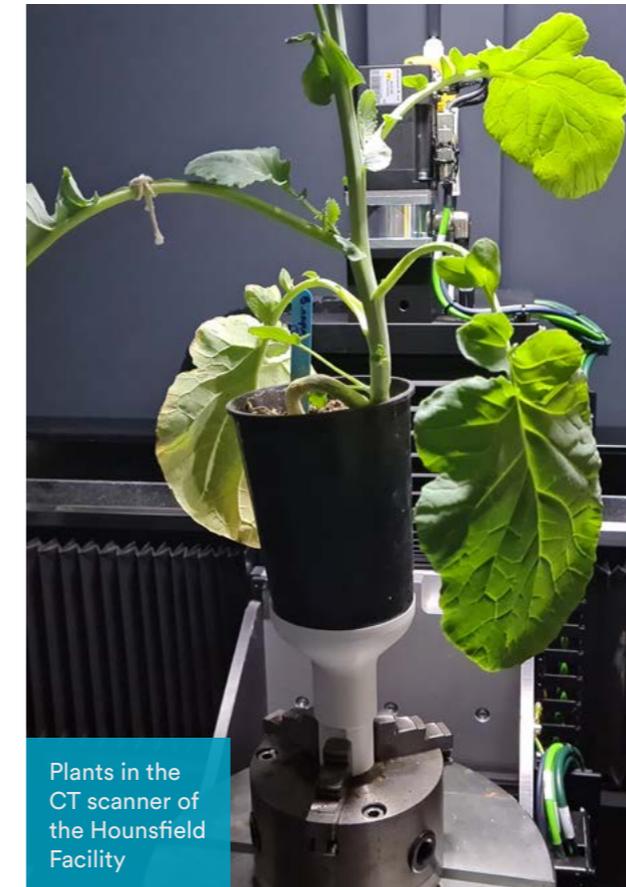
Degraded and low-copy DNA from ancient samples and the environment is used to address fundamental and applied questions in many disciplines, including evolution, plant science, environmental science, climate research, human diseases, and archaeology. ÆDNA will allow the analysis of ancient DNA from a variety of sources including archaeological material, herbarium and museum specimens, and sediments (for example, lake cores), and will allow us to analyse environmental DNA from water and soil samples.

This work is important to understanding how genetic diversity has changed over time, and has important implications for climate research, as these changes include adaptations to climate directly as well as climate-mediated effects on food production, biodiversity, invasive species, disease and extinction.



## MakerSpace

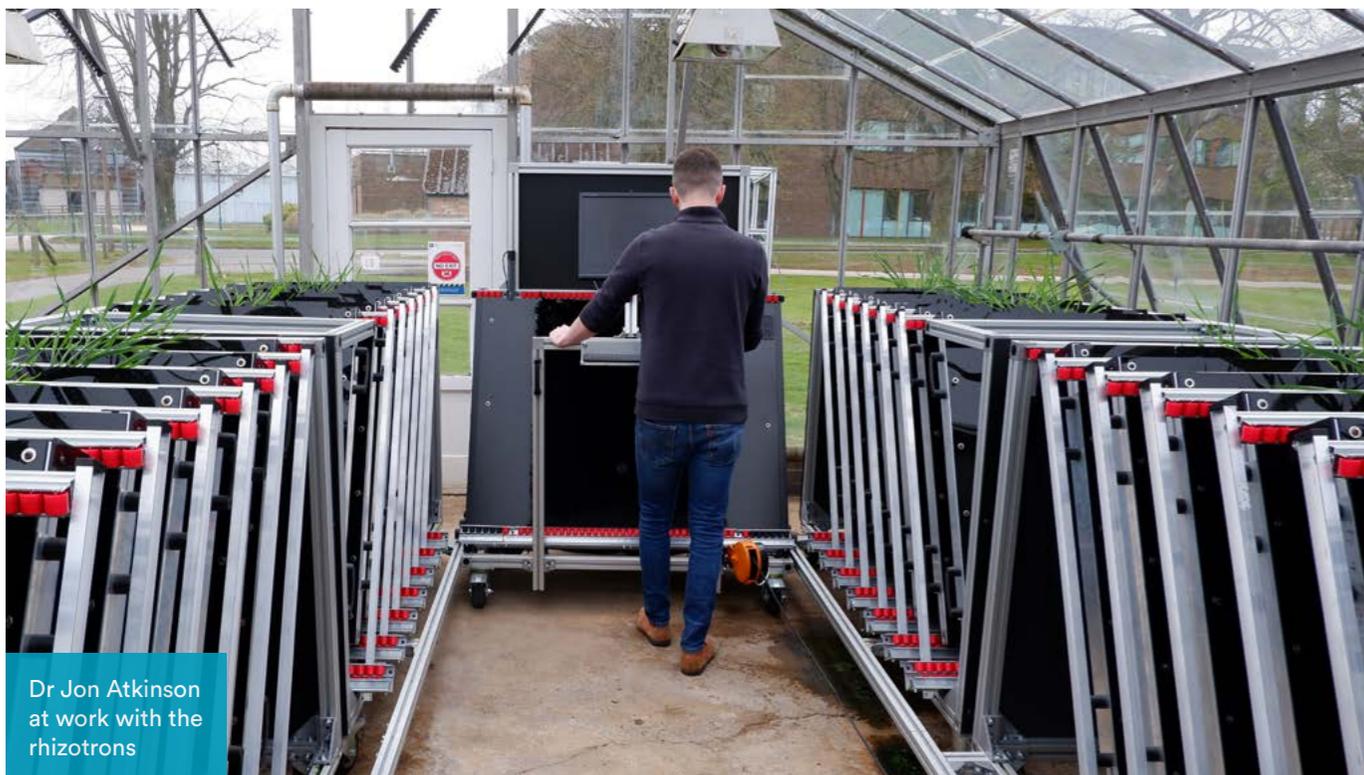
The MakerSpace is a design and innovation hub built to support research at the University of Nottingham. The main focus of the MakerSpace is plant phenotyping research, designing and deploying custom solutions to research questions that require monitoring of plant growth and development. Led by Dr Darren Wells and Beacon staff member Dr Jon Atkinson, the MakerSpace can design and build bespoke hardware for individual experiments.



Plants in the CT scanner of the Hounsfield Facility

This year, the MakerSpace has been involved in numerous projects, ranging from microscopy devices and robotic imaging systems, to much larger projects such as a rhizotron plant root imaging system and the modification of the Beacon-funded TraitFinder canopy scanning platform for use in the Hounsfield Facility. The MakerSpace has created custom column designs for a project studying the effects of soil compaction on roots using the X-ray CT scanners in the Hounsfield facility, and experimental setups to study wireworm activity for a studentship funded by Syngenta.

The MakerSpace has also recently built a system for artificially increasing the temperature of a crop canopy for use in a BBSRC Newton funded project researching the effects of increased night-time temperatures on wheat yields. As a result of climate change, night-time temperatures are increasing faster than day-time temperatures, and have been shown to have a detrimental effect on yields. The mechanism behind this yield loss is poorly understood. This system utilizes a feedback loop to maintain canopy temperature at a set threshold above ambient conditions by regulating an infra-red heating panel.



Dr Jon Atkinson at work with the rhizotrons

The MakerSpace has been involved in teaching this year, through the UKRI funded grant *Data CAMPP: Innovative Training in Data Capture, Analysis and Management for Plant Phenotyping*. *Data CAMPP*, led by Prof Andrew French of the Computer Vision Lab, aims to produce training material on all aspects of data driven plant phenotyping, covering data capture, automation, analysis, and processing. The MakerSpace has already produced material for initial introductory modules on data capture, covering examples ranging from basic plant phenotyping concepts to state-of-the-art equipment. Future modules currently in the design phase will include practical sessions (either in person or via a kit by post),

where attendees build their own phenotyping equipment using easily accessible electronic components and in-house designed and 3D printed parts. These kits will be based around recently published MakerSpace designs released for community use in the journal *Sensors*.

Interesting future MakerSpace projects currently in the planning and design stages include a portable entrainment device in collaboration with food scientists, a seed germination monitoring robot, and phenotyping solutions for the planned controlled environment facility expansion at Sutton Bonington.

## Molecular Phenomics Platform

The Molecular Phenomics Platform (MPP) was successfully commissioned in autumn 2020, and now resides within the analytical suite of the newly refurbished North Lab at Sutton Bonington. The LCMS system, consisting of a UHPLC front end and high-resolution Quadrupole-Time of Flight tandem mass spectrometer, can resolve thousands of chemical compounds in a single analytical run, across a wide range of concentrations.

In their first piece of work, the Molecular Phenomics Platform helped to explain metabolic difference between several *Arabidopsis thaliana* mutants and determine the interplay with the microbes colonising the root. The team developed a simplified profiling methodology, isolating >50k features across the study, with genotype, bacterial treatment and their interaction explaining 45% of total metabolome variance. This data was included as part of Gabriel Castrillo's recent *Science* paper, exploring how the microbiome influences plant absorption of mineral nutrients and trace elements from soil.



Subsequently, the Molecular Phenomics Platform have refined their workflow for untargeted analysis with the aim of improving the identification of significant molecular features in large data sets. They can now employ a variety of chromatography modes to give wider metabolome coverage, having developed several reverse phase, HILIC and lipidomics focussed methodologies. The team also routinely incorporate [Sirius software](#) as their main tool for *de-novo* identification of metabolites, which conveniently interfaces with a variety of online metabolomics databases. So far, this improved methodology has been used to identify compounds unique for a variety of brewing adjuncts used in large-scale brewing, and more recently to investigate how different brewing yeasts react to stress. The latter study showed that a common response of brewing yeasts to ethanol-induced stress is a major upregulation of lipid production, most notably several long chain fatty acids, linolic acids and fatty acid esters. The work suggests that hardier brewing yeasts may be able to remodel their cell membrane as an adaptive response to stress.

In the future the team will apply this methodology to a wide range of new projects. Following publication of a [new predictive model for fruit and vegetable intake](#), the Molecular Phenomics Platform will conduct a human intervention study, geared toward urinary identifying biomarkers of vegetable consumption. They will also assess how the cacao metabolome changes from harvest to the end of fermentation and attempt to correlate these changes with flavour attributes in chocolate.

## Ionomics platform

Based in the Gateway building, the Ionomics Facility provides researchers with large-scale phenotyping methods to decipher the functions of the genes and gene networks that regulate the ionome. This high-throughput elemental phenotyping platform is equipped with state-of-the-art inductively coupled plasma mass spectrometers (ICP-MS) and the sample preparation lab designed specifically for the high throughput preparation of samples for analysis by ICP-MS. Led by Beacon staff member Dr Paulina Flis, the Ionomics Facility offers measurement of the levels of up to 23 metals and non-metals in a given sample that allows researchers to address various biological questions within physiology, ecology, evolution, and other fields.

The Ionomics Facility works across multiple projects and has contributed to several outstanding works led by Future Food Beacon scientists. In a project led by Dr Gabriel Castrillo and published in *Science*, elemental phenotyping was used to understand how the interplay between microbiota and root diffusion barriers affects plant mineral nutrient homeostasis. The Ionomics Facility worked with Beacon postdoc Dr Guilhem Reyt on his project revealing the composition and formation of Casparian Strips in plant roots and the implications for mineral nutrient homeostasis.

The outcomes of this work were published in *Nature Communications* and *Current Biology*. Elemental profiling was also used to study arsenic metabolism and transport in plant roots. This work helped unravel the mechanism and cell type-specific functions of the arsenate reductase HAC1 protein in work published by the Beacon Research Fellow Dr Sina Fischer in the *Journal of Experimental Botany*.

The Ionomics Facility also participated in a research infrastructure project funded by Horizon 2020 EU Programme - the European Plant Phenotyping Network (EPPN2020). This research programme allowed many scientists across the world to establish collaborations and obtain funds to carry out ionomics experiments in the facility. The Ionomics Facility has now completed six out of eight accepted projects, collaborating with the Max Planck Institute, the Cocoa Research Centre at the University of the West Indies, the Kazakh Research Institute of Crop Production, the Vietnam Agricultural Genetics Institute, the Senegalese Institute of Agricultural Research, and the French Institution of Research for Development. These six completed EPPN projects have involved the analysis of over 16,500 samples by ICP-MS at the facility.



ICP-MS instrument in the Ionomics Facility

# Case study four: Project updates

People weeding  
around bambara  
groundnut plants

## Bambara groundnut

The Bambara groundnut breeding programme (BamBREED) is a collaborative effort involving researchers, farmers, government agencies and seed companies from South Africa (University of KwaZulu-Natal (UKZN)), Ghana (CSIR-Crops Research Institute (CRI)), Malaysia (University of Nottingham Malaysia (UNM)) and the UK (University of Nottingham).

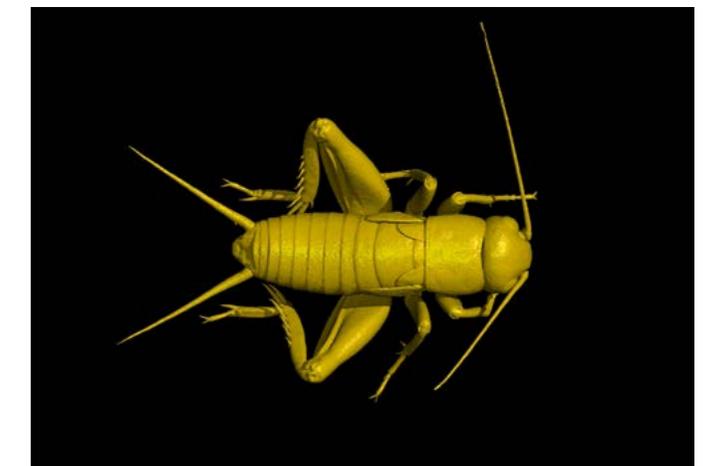
The programme has been supported by the Future Food Beacon, with external funding from the CFF-UNM DTP Impact Fund and Centre for Transformative Agricultural and Food Systems, UKZN. The programme's main aim is to develop a functional and long-term breeding programme, initially in two partner countries (South Africa and Ghana) and to register varieties in both countries. In addition to capacity development to support breeding and variety development in partner countries, the programme also aims to develop tools and approaches to allow for genetic trait dissection, generating genetic markers for potential use in Marker-Assisted Breeding (MAS). The sequencing of the Bambara groundnut genome is ongoing at Deep Seq, supported by the Beacon's sequencing and bioinformatics capabilities.

So far, the programme has supported and trained five PDRAs and five PhD students. Working with partners, the programme is currently overseeing five structured Bambara groundnut populations at various stages of development, 20 superior lines (single genotypes) at various stages of field evaluation for registration as new varieties in Ghana, and 12 elite breeding lines under various

stages of advancement for registration and release as new varieties in South Africa. The research work focused on Bambara groundnut has helped UoN secure funding as a partner on the RADIANT H2020 project (1st September 2021 – 31st August 2025; £168,000) to investigate whether this is a useful crop for southern Europe. Four papers have been published based on this research work.

## The Future Proteins Platform

Despite the challenges of the Covid-19 pandemic, the Future Proteins Platform has continued to make progress on their various projects developing alternative sources of proteins, an area of research clearly identified by the National Food Strategy as being important. The Platform is now benefitting from the move of the Nutrition Group into the newly refurbished North Laboratory on Sutton Bonington and the establishment of a state of the art facility for nutritional analysis, with much equipment supplied by the Future Food Beacon, including a bomb calorimeter, plate reader, Dionex ICS and Soxhlet fat extractor.



This facility will support existing and future research projects and funding bids, and places the University in a strong position to attract contract research from both industry and other academic institutions.

We welcome an additional PhD student, Noriane Cochetel, to the team. Noriane is focusing on the digestibility of proteins from single-cell organisms, and her PhD is co-funded by animal feed company ABAgri. Current PhD candidate, Ann Jo Tee won 2nd prize at the International Congress of the Malaysian Society for Microbiology 2021 for her rapid oral presentation on the impact of fermentation on anti-nutrient activity of the Bambara groundnut.

The two postdoctoral researchers on the Future Proteins Platform have continued to develop their work, despite the pandemic. Dr Molly Muleya has undertaken a desk-based study, using data from a recent Household Survey in Malawi to estimate amino acid availability in the Malawian diet. Her findings, highlighting the vulnerability of the lowest socio-economic groups in the country to amino acid deficiency, is being prepared for publication. Molly is now establishing a robust method for the *in vitro* determination of the amino acid digestibility of foods. Molly is working with the INFOGEST Group of over 500 scientists to develop a standardised method for *in vitro* digestion.

Dr Carlos Lopez Viso has been using the recently acquired mealworm genome sequence, delivered by Deep Seq through Beacon funding and support, to identify genes associated with growth and composition in mealworms. These identified



genes will be manipulated to improve production efficiency and nutritional composition of larvae for inclusion in animal feeds as an alternative protein source to replace feed ingredients such as maize and soybean that could be eaten by people. Furthermore, meal worms can be fed on various waste materials such as straw, that cannot be easily consumed in animal feed, providing a more sustainable solution to raising livestock such as chickens. The Future Proteins Platform has been specifically examining the impact of endocrine factors which regulate the lifecycle of mealworms, and the genes they regulate, as potential candidates for manipulation.

The Future Proteins team are moving towards completing many projects and publishing results. They have submitted applications for further external funding to BBSRC, UKRI, and the Royal Society.



## PalaeoRAS

2021 was the second year for most of the PalaeoRAS PhD students and as such has been a key time of data collection. Covid-19 has seen a shift to more modelling components of our projects, Bowen Deng (Computer Science), Rik Rutjens (Maths) and Amit Kumar (Geography) continue to work on innovative approaches to image analysis, plant, and drought models respectively. Fieldwork has continued to be a challenge, but Karla Hernandez Aguilar (Geography) was able to revisit field sites in the Yucutan of Mexico, Anne Veecken (Geography) undertook fieldwork in Scotland to benchmark her trait-based models and we're grateful to our collaborator Khaled Al Masaed for helping with some of Ali Ben Mustapha's (also Geography) fieldwork in Jordan. In the lab Aneesh Lale and Faidra Katsi (both Bioscience) have been working on root and pollen systems,

with a view to understanding the impacts of heat and water stress on these respectively. Preliminary results of all these projects are really exciting and initial phases of the work will be appearing in journal articles soon.

Jordan Robson (Bioscience) joined the PalaeoRAS team this year, replacing John Ferguson as one of the project's Research Fellows as John moved on to new pastures. We thank John for all his work and support as the PalaeoRAS projects got up and running. Jordan continues the project's work on the effects of heat on rice growth. Elsewhere it's exciting to see the new Ancient and Environmental DNA lab nearing completion and ready to process its first samples. This is a great resource to continue work in the PalaeoRAS space for years to come, Andrew Clarke (Bioscience) will be happy to hear from you if you would like to learn more about this facility.

## Cocoa beans

We have two projects focused on the cocoa bean. The first, funded by Innovate UK, concerns the role of fermentation in the final chocolate flavour. The second, funded by MARS, examines the problem of cadmium uptake in cocoa beans.

Quality and flavour of cocoa beans are important for the value of chocolate, and fermentation is a key step in developing flavour. Fermentation of cocoa beans is a spontaneous process that reduces bitterness and astringency in the beans while stimulating the development of desirable aromas and flavours. It is typically carried out on cocoa farms, and microbes from the surrounding environment contribute to the creation of unique local flavours.

In partnership with Federación Nacional de Cacaoteros (FEDECACAO) and Casa Luker Chocolate in Colombia, Luisa's Vegan Chocolates in Nottingham, and the Cocoa Research Centre in Trinidad, our researchers travelled to Colombia in 2019 to analyse microbial samples from three smallholder female farmers. The three cocoa-growing regions where the farms are located are well known for their uniquely flavoured beans. Using portable Oxford Nanopore DNA sequencers, researchers analysed the microbial communities of the fermenting beans, as well as the surrounding farm. Harvested beans were shipped to Luisa's to be made into chocolate.

Marked differences have been found in the types and abundance of microbes in the three regions, which appear to contribute to the different flavours of the final chocolates.



Cocoa fermentation

Potential sources of these microbes from the surrounding environment were identified. This research will help farmers understand the processes of fermentation better, and can lead to better quality, more flavoursome beans.

Another challenge facing cocoa farmers is the problem of cadmium uptake by cocoa beans. Cadmium is a potentially toxic heavy metal that can be found in various foods through bioaccumulation from the soil. Cocoa trees can absorb the cadmium in the soil, and accumulate it in different parts of the plant, including the beans.

This poses a concern for food safety as that cadmium is then in the finished chocolate product. The EU has implemented maximum limits on the amount of cadmium allowed in final chocolates. Limits apply to finished products but farmers are likely to encounter export problems if their beans are elevated in cadmium. This is particularly concerning for growers in Latin America and the Caribbean, where cadmium in cocoa is higher due to increased levels of cadmium naturally occurring in the soil.

Partnering with the Cocoa Research Centre (CRC) at the University of the West Indies, we are exploring ways to reduce cadmium accumulation in cocoa beans by identifying genetic markers linked to low cadmium absorption. The CRC is the custodian of the International Cocoa Genebank, and has a collection of over 2400 cocoa varieties – regarded as the largest and most diverse cocoa collection in the public domain.

Our researchers have screened the leaves and beans of more than 500 cocoa varieties for differences in cadmium accumulation. They have found a more than 10-fold difference in accumulation between the highest and lowest cadmium concentrations. Significant differences have been observed between the different fractions analysed, and was highest in the leaf, then cotyledon, and lowest in the testa (the hard external coating) of the bean. Researchers sequenced the genomes of 500 varieties of cocoa and performed a genome-wide association study (GWAS) for cadmium accumulation in different parts of the cocoa plant, including leaves and beans. GWAS mapping detected multiple genetic loci associated with variation in leaf and bean cadmium. We are in the process of validating these genetic loci. Once validated they will be used to develop molecular markers for screening varieties of cocoa for those with root stocks that produce cocoa beans low in cadmium, and used to help breed low cadmium varieties of cocoa in the future.

# Beacon leadership team



**David Salt**  
Director of the  
Beacon, Faculty  
of Science



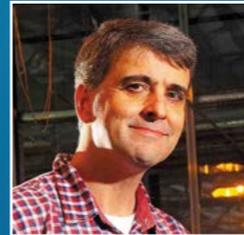
**Richard Emes**  
School of  
Veterinary  
Medicine and  
Science



**Matt Loose**  
School of Life  
Sciences



**Tania Dottorini**  
School of  
Veterinary  
Medicine and  
Science



**Malcolm Bennett**  
School of  
Biosciences



**Darren Wells**  
School of  
Biosciences



**Martin Broadley**  
School of  
Biosciences



**Richard Hyde**  
School of Law



**Ramiro Alberio**  
School of  
Biosciences



**Anne Touboulc**  
Business School



**Debbie Sparkes**  
School of  
Biosciences



**Kate Millar**  
Director, Centre  
for Applied  
Bioethics



**Andy Salter**  
School of  
Biosciences



**Tony Pridmore**  
School of  
Computer  
Science



**Markus Owen**  
School of  
Mathematical  
Sciences



**Heike Bartel**  
School of  
Cultures,  
Languages and  
Area Studies



**Richard Worrall**  
Head of Food  
Innovation Centre



**Kevin Sinclair**  
School of  
Biosciences



**Festo Massawe**  
School of  
Biosciences,  
Malaysia campus



**Nik Watson**  
Department of  
Chemical and  
Environmental  
Engineering

# Beacon staff

**Professor David E Salt**  
Director of Future Food  
Beacon, Professor of  
Genome Enabled Biology

**Professor Murray Lark**  
Professor of Environmetrics

**Professor Levi Yant**  
Associate Professor in  
Evolutionary Genomics

**Assistant Professor  
Tristan Dew**  
Assistant Professor in  
Molecular Phenomics

**Assistant Professor  
Andrew Clarke**  
Assistant Professor in  
Archaeogenetics

**Assistant Professor  
Guillermina Mendiondo**  
Assistant Professor in  
Translational Crop Science

**Assistant Professor  
Rahul Bhosale**  
Assistant Professor in Crop  
Functional Genomics

**Assistant Professor  
Sina Fischer**  
Assistant Professor in  
Functional Genomics

**Assistant Professor  
Sally Eldeghaidy**  
Assistant Professor in  
Sensory Science

**Associate Professor  
Gabriel Castrillo**  
Associate Professor in  
Plant Microbiome

**Associate Professor  
Michael Pound**  
Associate Professor in  
Computer Vision

**Dr Chris Moore**  
Senior Research Fellow and  
Technologist in Genomics

**Dr Jonathan Atkinson**  
Senior Research Fellow and  
Technologist in Phenomics

**Dr Peter Craigon**  
Postdoctoral Research Fellow

**Dr Molly Muleya**  
Postdoctoral Research Fellow

**Dr Carlos Lopez-Viso**  
Postdoctoral Research Fellow

**Dr Jordan Robson**  
Postdoctoral Research Fellow

**Simon Ridgway**  
Associate Director for  
Operations

**Dr Peter Noy**  
Associate Director for  
Research

**Dr Lexi Earl**  
Outreach and Engagement  
Manager

**Joanna Smuga-Lumatz**  
Administrator

**Gigi Walker**  
Administrative Assistant



University of  
**Nottingham**  
Future Food

# Discover more about our world-class research

[nottingham.ac.uk/future-food](https://nottingham.ac.uk/future-food)

 [SB-future-food@nottingham.ac.uk](mailto:SB-future-food@nottingham.ac.uk)

 [@UoNFutureFood](https://twitter.com/UoNFutureFood)

 [/future-food-beacon](https://www.linkedin.com/company/future-food-beacon)

 [blogs.nottingham.ac.uk/futurefood](https://blogs.nottingham.ac.uk/futurefood)

This publication is available  
in alternative formats.  
**+44 (0)115 951 5559**