Internationalisation is at the heart of everything we do as a University and as described by the Sunday Times, we are proud to be “the embodiment of the modern international university”. We collaborate with institutions from around the world to address global challenge agendas and regard internationalisation as fundamental to our long term partnerships. It is our vision to be recognised around the world for our signature contributions, especially in global food security, energy and sustainability, and health.

Our UK estate

The University of Nottingham is based on several locations, with our University Park Campus being the largest at 300 acres and widely regarded as one of the most attractive in the country. Support for the food and drink industry is spread across these locations demonstrating the multidisciplinary nature of our expertise. The University Park campus is home to such schools as Engineering, Chemistry, Pharmacy, Manufacturing, and Psychology and includes state of the art human imaging facilities and other related disciplines.

Our Sutton Bonington Campus is home to the School of Veterinary Medicine and Science (the UK’s first new Vet School since the 1960s). The School of Biosciences is also based there and is today an internationally renowned centre for cutting edge research in Animal Sciences, Food Sciences, Plant and Crop Sciences, Nutritional Sciences and Agricultural and Environmental Sciences. This is further complemented by expertise in Life, Health and Medical Sciences with facilities at the University’s Medical School Campus and at the adjacent University Park Campus. This provides the food and drink industry with excellent and easy access to some of the best expertise and facilities anywhere in the world.

Our International campuses

China – Ningbo Campus

The University’s strong links with China resulted in an invitation to become the first foreign university to establish an independent campus. Research in China is embodied through our strategic partnership agreement with China Agriculture University, Beijing as its only UK strategic partner to develop joint research and study opportunities in Crop Science, Bioenergy, Nutrition, Veterinary Medicine and Animal Sciences. This is an exciting development for both Universities placing the partnership in a strong position to tackle together major global challenges related to food security and health.

Malaysia – Semenyih Campus

This new purpose-built campus at Semenyih, 30km south of Kuala Lumpur city centre co-hosts the first ever Crops for the Future Research Centre (CFFRC); an exciting new venture between the Government of Malaysia and The University of Nottingham. The centre is specifically designed to evaluate underutilised crops from all corners of the world. It will be at the heart of an international effort to seek out which crops have the potential to be grown for human sustenance or on a commercial basis for food, pharmaceutical or biomaterials in the climates of the future.

International collaboration with The University of Nottingham is a strategic opportunity to build on the University’s reputation for research excellence and its vast experience in developing global research partnerships and collaborations.

CONTACT

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Corporate Partnerships Senior Executive
Food & Drink Sector
Mobile: 07818 508755
Email: amreesh.mishra@nottingham.ac.uk

For further details see www.nottingham.ac.uk/servicesforbusiness
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The University of Nottingham and the food and drink industry

As the largest manufacturing sector in the UK, Food and Drink has a fundamental role to play in boosting exports and encouraging a resource efficient and vibrant economy, maintaining our national competitiveness and protecting the UK’s Food Security. We need to produce more from less and with reduced impact to meet growing global demand and the consequences of climate change.

Unlocking the full potential of what science can contribute to delivering sustainable growth to the largest manufacturing sector in the UK is a fundamental challenge. This capability document is structured to help the food and drink industry navigate and better access The University of Nottingham’s expertise such that its industry leading knowledge can be applied in helping to address challenges faced by the food and drink sector.

The University of Nottingham is home to one of the largest communities of plant, crop, nutrition, animal and food science experts in the UK together with additional expertise on its campuses in China and Malaysia. With its network of international campuses the University is ideally placed scientifically, geographically and politically to undertake high-calibre multidisciplinary research from farm to fork and find new ways of feeding a hungry planet. Our internationally acclaimed research is also focused on the sustainable provision of a safe and secure supply of nutritious food and as such The University of Nottingham has been awarded the Queen’s Anniversary Prize for Higher & Further Education. This is in recognition of its cutting-edge research in Global Food Security that helps feed the world’s growing population – work which encompasses everything from growing more crops with less fertiliser, to improving the nutrition, safety and taste of food on the plate.

We also host the EPSRC Centre for Innovative Manufacturing in Food. This is focused on utilising a ‘Food System’ approach to provide a resource efficient and secure future for the UK food industry. The Centre will tackle research related to the development of Innovative materials, products and processes and sustainable food supply and manufacture.

The entire agri-food supply chain, from agriculture to final retailing and catering, is estimated to contribute £96bn to the economy and employ 3.8 million people (*source: Agri-Tech launch July 2013).
Three key initiatives

Industry, government and research communities are transforming the way they work together in delivering a shared agenda for sustainable growth across the whole supply chain from seed to digestion.

This document references three specific initiatives:

1. A UK strategy for agricultural technologies launched in July 2013
   www.gov.uk/government/publications/uk-agricultural-technologies-strategy

2. Priority research questions for the UK food system
   www.foodsecurity.ac.uk/assets/pdfs/priority-research-questions-uk-food-system.pdf
   2.1 Production issue: What are the opportunities and risks for UK food supply and primary production in responding to climate change?
   2.2 Manufacture issue: How can the fat, sugar, preservative and salt content of foods be reduced while ensuring that palatability is maintained, waste is minimised, and food remains safe and does not spoil?
   2.3 Behaviour issue: Which intervention (or combination of interventions) would be most effective in achieving changes in consumption decisions and which interventions (e.g. awareness raising campaigns, choice editing, education, legislation or regulatory) are most appropriate for specific contexts and decisions?

3. A recent initiative carried out by the food sector Knowledge Transfer Network (KTN), the National Technology Platform for Food (NTP) and the Food and Drink Federation (FDF) mapping out the precompetitive scientific landscape.
   www.fdf.org.uk/events/Pre-comp-Food-Booklet-Final.pdf

How to read and use this document

The University of Nottingham ‘food chain’ expertise is captured within the capability matrix on pages 10 to 15 and is illustrated from primary production through to consumption and digestion (Behaviour, Consumer Health and Clinical Application).

The capability matrix not only identifies The University of Nottingham’s expertise across the whole supply chain but also where it sits within the ten key pre-competitive research areas (initiative 3 listed on page 8) and the top three research questions in the areas of ‘production’, ‘manufacturing’ and consumer ‘behavioural’ aspects of the food system (initiative 2 listed on page 8).

The individual matrix cells indicate just some of the relevant key research capabilities offered by the University. These are discussed in further detail in the categories listed alphabetically, where you can find out more about the academics and their teams carrying out the world leading research in these areas.

The expertise is colour coded which allows for ease of identification and is referenced to the A-Z categories detailed within the main document, from page 16 onwards. In addition, navigating from the matrix is made easier allowing you to click the capability within the matrix cell which then takes you straight to the corresponding alphabetical listing. Throughout the document you will also be able to click on named contacts and centres providing further detail on the areas of expertise.

Priority areas for research to maintain and enhance the UK’s competitive position in global food manufacture

- Primary production
- Post-harvest
- New ingredients, development
- Food engineering and processing
- Behaviour, consumer health and clinical applications
### The University of Nottingham

#### Research capability matrix

<table>
<thead>
<tr>
<th>Top 10 global research areas</th>
<th>Global food security project: - top 3 questions.</th>
<th>Primary production</th>
<th>Post-harvest</th>
<th>New ingredients, development</th>
<th>Food engineering and processing</th>
<th>Behaviour, consumer health and clinical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Food Safety</strong></td>
<td>M, B</td>
<td>- Animal Infection and Immunity</td>
<td>- Corporate Social Responsibility</td>
<td>- Corporate Social Responsibility</td>
<td>- Industrial Microwave Processing</td>
<td>- Nutrition, Diet and Health</td>
</tr>
<tr>
<td><strong>2. Authenticity and traceability</strong></td>
<td>P, M, B</td>
<td>- Animal Science</td>
<td>- Corporate Social Responsibility</td>
<td>- Corporate Social Responsibility</td>
<td>- Microbiology and Food Safety</td>
<td>- Corporate Social Responsibility</td>
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<tr>
<td><strong>4. Next generation retail</strong></td>
<td>M, B</td>
<td>- Veterinary Science</td>
<td>- Food Innovation and Processing</td>
<td>- Food Innovation and Processing</td>
<td>- Innovative Manufacturing in Food</td>
<td>- Corporate Social Responsibility</td>
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<tr>
<td><strong>5. New and smarter ingredients</strong></td>
<td>P, M, B</td>
<td>- Brewing</td>
<td>- Brewing</td>
<td>- Brewing</td>
<td>- Innovative Manufacturing in Food</td>
<td>- Corporate Social Responsibility</td>
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<tr>
<td><strong>6. Smarter packaging</strong></td>
<td>M, B</td>
<td>- Flavour Analysis</td>
<td>- Brewing</td>
<td>- Brewing</td>
<td>- Innovative Manufacturing in Food</td>
<td>- Corporate Social Responsibility</td>
</tr>
</tbody>
</table>

**KEY RESEARCH CAPABILITIES**

- Animal Infection and Immunity
- Animal Science
- Comparative Medicine Group
- Veterinary Science
- Corporate Social Responsibility
- Human Factors in Manufacturing
- Food Innovation and Processing
- Industrial Microwave Processing
- Microbiology and Food Safety
- Nutritional and Diet Health
- Brewing
- Corporate Social Responsibility
- Human Factors in User Behaviour and Diet
- Nutrition, Diet and Health
- Resource Efficiency
- Sensory Science
- Bioenergy
- Biomaterials: Products, Properties and Processing
- Innovation in Food
- Nutritional and Diet Health
- Sensory Science
<table>
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<tr>
<th>Top 10 global research areas</th>
<th>Global food security project - top 3 questions. P: primary production M: manufacturing B: behavioural</th>
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<tbody>
<tr>
<td><strong>7. Health and wellbeing through diet</strong></td>
<td><strong>Primary production</strong> - Animal Science - Nutrition, Diet and Health - Plant Integrative Biology <strong>Post-harvest</strong> - Post-harvest Biotechnology <strong>New ingredients, development</strong> - Chemical Sciences - Microbiology and Food Safety - Nutrition, Diet and Health - Synthetic Biology <strong>Food engineering and processing</strong> - Innovative Manufacturing in Food <strong>Behaviour, consumer health and clinical applications</strong> - Biomaterials: Products, Properties and Processing - Bioproducts - Digestive Physiology and Pathology - In-body Imaging of Food and Drink - Microbiology and Food Safety - Nutrition, Diet and Health</td>
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<td><strong>KEY RESEARCH CAPABILITIES</strong></td>
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<td>Chemical Sciences - Microbiology and Food Safety - Nutrition, Diet and Health - Synthetic Biology</td>
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<td><strong>KEY RESEARCH CAPABILITIES</strong></td>
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<td>Chemical Sciences - Corporate Social Responsibility - Resource Efficiency</td>
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<td><strong>KEY RESEARCH CAPABILITIES</strong></td>
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<td>Chemical Sciences - Corporate Social Responsibility - Resource Efficiency</td>
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<td><strong>KEY RESEARCH CAPABILITIES</strong></td>
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<td>Chemical Sciences - Energy Efficiency - Industrial Microwave Processing - Innovative Manufacturing in Food - Resource Efficiency</td>
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</table>
## Food and Drink Capability Statement

<table>
<thead>
<tr>
<th>Additional University expertise</th>
<th>Key Research Capabilities</th>
<th>Food Engineering and Processing</th>
<th>Behaviour, Consumer Health and Clinical Applications</th>
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</thead>
<tbody>
<tr>
<td><strong>Primary production</strong></td>
<td><strong>Measurement and analytics</strong></td>
<td><strong>Ethics</strong></td>
<td><strong>Politics, Policy and Economics</strong></td>
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<td>- Animal Population Health &amp; Welfare</td>
<td>- Corporate Social Responsibility</td>
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<td>- Applied Optics</td>
<td>- Food and Agricultural Ethics</td>
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<td>- Big Data</td>
<td>- Animal Science</td>
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<td>- Biosensors</td>
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<td>- Geomechanics</td>
<td>- Rural and Environmental Science</td>
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<td>- Mathematical Modelling</td>
<td>- University Farm</td>
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<td>- Nanoscale</td>
<td>- Animal Science</td>
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<td>- Plant Integrative Biology</td>
<td>- Animal Science</td>
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<td>- 3D Imaging through X-rays (MicroCT)</td>
<td>- Animal Science</td>
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<td><strong>Post-harvest</strong></td>
<td><strong>New ingredients, development</strong></td>
<td><strong>Innovation and facilitation</strong></td>
<td><strong>Education and training</strong></td>
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<td>- Digital Economy Research</td>
<td>- Animal Science</td>
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<td>- Geospatial Science</td>
<td>- BBSRC Agrifood Advance Training Partnership</td>
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<td>- Innovation Support for Business</td>
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<td>- Food and Biomedical Macromolecules</td>
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</tbody>
</table>

**Ethics**

- Corporate Social Responsibility
- Food and Agricultural Ethics

**Politics, Policy and Economics**

- Animal Science
- Global Food Security
- Resource Efficiency
- Rural Business Research
- Rural and Environmental Science
- University Farm
- Resource Efficiency
- Rural and Environmental Science
- University Farm

**Innovation and facilitation**

- Animal Science
- Digital Economy Research
- Geospatial Positioning for Farming, Precision Agriculture and Global Food Security
- Geospatial Science
- Reproductive Biology
- Rural and Environmental Science
- Digital Economy Research
- Geospatial Science
- Innovation Support for Business
- Rural and Environmental Science

**Education and training**

- Animal Science
- BBSRC Agrifood Advance Training Partnership
- BBSRC Doctoral Training Partnership
- Chemical Sciences
- Continuing Professional Development
- European Arabidopsis Stock Centre
- Animal Science
- BBSRC Agrifood Advance Training Partnership
- BBSRC Doctoral Training Partnership
- Chemical Sciences
- Continuing Professional Development
- BBSRC Agrifood Advance Training Partnership
- BBSRC Doctoral Training Partnership
- Chemical Sciences
- Continuing Professional Development
- Nutrition, Diet and Health
A-Z of food and drink expertise at The University of Nottingham

Adaptive Bioprocessing

Key contact: Rafael Gomes

Economic incentives are encouraging new approaches to manage manufacturing resources and treat wastes, enabling reuse, recovery of value products and possible safe release into the environment of waste products. Processes where bio-sourced feedstocks or catalysts are used are of particular interest as this is where inherent variability of the bio-input increases the system complexity.

Key research expertise includes: product analysis in advanced manufacturing, (chemical and energy products).

Advanced Manufacturing

Key contacts: Paul Hamley, Svetan Ratchev

The Institute for Advanced Manufacturing (I4AM) encompasses a multidisciplinary team of established academics in their respective fields in the UK and at our campuses in Malaysia and China. This provides the foundation needed for research and world-leading facilities to encourage the development of new technologies and systems for production of high-value products within the manufacturing sector.

I4AM is dedicated to supporting UK manufacturing to revitalise the British economy through innovation and collaboration. The research portfolio at the institute presents a unique and holistic approach to manufacturing.

Current research is concerned with developing new technologies and systems for cost efficient, knowledge intensive, high value and environmentally friendly production. I4AM addresses the full product lifecycle from development through to manufacture, usage and disposal.

Animal Infection and Immunity

Key contact: Paul Barrow

The Animal Infection and Immunity Group are partaking in wide-ranging research which involves bacterial pathogens (Clostridium, Campylobacter, Listeria, Streptococcus, Salmonella, Vibrio and Mycobacteria), viruses (including Influenza - avian and mammalian species, Malignant catarrhal fever (MCF), Equine herpesvirus, Equine Arteritis Virus, and endogenous retroviruses), prions (including transmissible spongiform encephalopathies) and parasites (ranging from intracellular protozoa, such as Toxoplasma gondii and Neospora caninum, to large multicellular worms including Fasciola hepatica). The range of hosts studied are pigs, poultry, mice, cows, horses, dogs, deer and wild animals.

The European FP7 project Wildtech is developing novel techniques for surveillance of emerging and re-emerging infections in wildlife.

Agriculture Machine Drives

Key contact: Chris Gerada

The research expertise lies in integrated motor-drive solutions for traction, energy recovery actuation and processing. The aim is to generate significant gains in efficiency, fuel savings and reduced emissions which can be attained by moving from traditional mechanical and hydraulic systems to electrical ones. The University's high power density brushless machines, designed by the world-leading electro-mechanical research group at Nottingham, can be applied to food processing, water spraying, tractor traction and other mechanical processes.

Analytical Biosciences

Nottingham's Centre for Analytical Biosciences

(School of Pharmacy)

Key contact: David Barrett

Researchers in this Centre apply advanced analytical approaches to investigate complex biological and pharmaceutical problems. Current studies involve the need to analyse multi-component mixtures of molecules in human, mammalian, bacterial, plant or food samples. A major area of investigation is the role of biological metabolites in important biological processes and disease states, particularly using metabolomics.

Meat Science

(Nutritional Sciences Division, School of Biosciences)

As a result of better agricultural and food processing methods and improved public health, the world's population has reached seven billion and anticipated to reach nine billion by 2050. This projected population increase will involve an additional annual consumption of 200 million metric tons of meat. Research in this area includes: molecular aspects of protein and enzyme biochemistry with particular relevance to muscle structure and function in farm species; the function of the calcium-activated proteases in muscle growth and in meat tenderness in pigs and in ruminants; identification of SNPs of relevance to meat quality and growth; the potential role of other proteolytic enzymes in the development of tender meat and the effect of modifying the composition of feed to enhance tenderisation and thereby meat quality.

Animal Nutrition

Key contacts: John Brameld, Phil Garnsworthy, Tim Parr, Andy Salter, Julian Wiseman

Livestock Nutrition

(Animal Sciences Division, School of Biosciences)

Research includes all aspects of the animal production chain from evaluation of feed raw materials, through responses to nutrition in terms of animal performance, fertility and health, to enhancement of milk and meat quality. Emphasis is on dairy and beef cattle, sheep, pigs and poultry. A major objective is to improve feed efficiency in livestock production systems whilst reducing their environmental impact and improving product quality.
Food and Drink Capability Statement

Animal Science
Animal Sciences Division, School of Biosciences
Key contacts: Phil Garnsworthy, Julian Wiseman

The Animal Sciences Division has an international reputation for research in animal nutrition, development, reproduction and biotechnology. Research in Animal Science focuses in six primary areas:

Animal production
Our focus is on major livestock species by studying feed efficiency and sustainability in animal systems, nutritional strategies for enhancing dairy cow fertility, nutritional value of dietary raw materials, environmental impact of methane emissions, effects of exposure to environmental chemicals on development of the foetal hypothamic-pituitary-gonadal axis and product quality (e.g. modifying fatty acid profile of milk) through changes to diets.

Reproduction
The physiology of reproduction, particularly improving or regulating fertility, is mostly on domestic mammalian species, but we relate findings to human and animal medicine. We study the pituitary-ovarian-uterine axis, including oocyte development, folliculogenesis, ovulation, formation of the corpus luteum, maternal recognition of pregnancy, conceptus development and the impact of assisted reproductive technologies (ART) in the long term health of animals.

Development
The team are investigating the developmental mechanisms involved in generation of pluripotent cells. Our aim is to understand the molecular basis of pluripotency, and use the strategies employed by the embryo to recapitulate these events in laboratory conditions that will enable the manipulation of somatic cells to serve as a valuable model for gene targeting and for the generation of animal models of human disease. We use pig embryonic stem cells as a model system for studying development by examining growth factor signalling in muscle development, microRNAs in myogenesis, origins of adipose tissue, and regulation of limb muscle formation.

Epigenetics
Ongoing research is addressing how maternal nutrition can programme foetal development and adult health via heritable epigenetic changes to DNA methylation. In addition to mammalian work, the honeybee is used as a model organism. Changes in the activity of honeybee genes have been linked to one of the recently banned neonicotinoids that may affect energy metabolism and the stability of developmental processes that could augment the impact of additional stressors such as pests, disease and bad weather and influence bee health.

Neuroscience
Our research goals are increasing the understanding of pain systems, how they are modulated following injury / inflammation and how best to treat pain. The group are founder members of the Arthritis Research UK Pain Centre (Nottingham) established to increase the understanding of arthritis pain mechanisms and its treatment.

Bioethics
Our team is amongst the few international groups of researchers who focus on animal, agricultural and food ethics. The research being conducted is on integrated biotechnology assessment and policy-making; development of ethical tools; ethical dimensions of the human use of animals, making science public and the role of stakeholder engagement.

Animal Population Health & Welfare
Key contacts: Paul Barrow, Malcolm Cobb, Gary England, Martin Green

A number of projects are examining how early environment (and interactions with the genome) may influence susceptibility to non-communicable disease such as obesity, metabolic syndrome and hyper-tension. Nutrition is the predominant environmental variable that is manipulated. Species groups investigated include: companion animals; production and performance animals; laboratory animals; zoo, wildlife and exotics. Expertise includes: epidemiology and statistical biology; study design and epidemiological modelling, bioinformatics, molecular epidemiology, evidence-based veterinary medicine and laboratory diagnostics.
Food and Drink Capability Statement

**Big Data**

**Informatics, Intelligent Modelling and Analysis and Nottingham Geospatial Institute and the Advanced Data Analysis Centre**

**Key contacts:** Ian Dryden, Jon Garibaldi

The availability of very large data sets, together with smart technology, is enabling advances in information technology applied to the food sector including: geospatial mapping for smart agriculture; geospatial risk assessment re species and pests; genetic trait diversity in animal and crop breeding; crop selection and climate change analysis, and Smart sensing devices.

The **Advanced Data Analysis Centre (ADAC)** was established in 2012 in the University of Nottingham to provide a vital infrastructure service to undertake advanced data analysis in multi-disciplinary contexts, without requiring fundamental research into the data analysis itself. ADAC offers skilled data analysis expertise, across the entire portfolio of academic subject areas and application context, which can be utilised by anyone within the University. It is increasingly the case that the data being generated by research projects in all academic areas within the University is growing in size and complexity, and that the requirements for appropriate analysis of this data are becoming more sophisticated.

The remit of ADAC is to analyse such complex and large data sets assembled by University researchers. ‘Complex data’ is specified as being beyond the normal comfort-zone of the researchers possessing the data; it is recognised that academics from various disciplines possess differing skill levels and ADAC provides services as required by the client end-users. ADAC has found significant demand from within the domain of food and drink and in particular responding to requests to assist with large genetic datasets from various food sources (such as rice, barley and tomato plants).

ADAC also provides training in data analysis, assistance in preparation of academic publications and funding proposals, and consultancy services to industrial partners. By providing a permanent central data analysis service across the University, ADAC is able to supply data analysis on a bespoke basis to individual projects without restriction on quantity or duration of analysis required, obviating the potential problem of attempting to appoint short-term data analyst posts.

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**Applied Optics**

**Key contacts:** John Crowe, Barrie Hayes-Gill

Our expertise is in developing novel instrumentation to monitor human physiology; an approach which can also be generalised to other animals and biological tissues e.g. the tailoring of LED lighting to control plant growth. Other plausible areas of investigation include the use of novel quantitative spectroscopy techniques in cereal crop monitoring, and the use of thermal/microwave imaging to detect brown fat temperature.

**Key contact:** Serhiy Korposh

The work focuses on the development of fibre optic chemical sensors with a functionalised sensitive layer to detect specific chemical compounds in liquids and in air. Specific applications include: detecting indoor/outdoor air contaminants, measuring bulk refractive index change of a liquid sample in real time, and in monitoring chemical and bio compound binding reactions and deposition.

**Applied Optics**
Bioenergy

Bioethanol

Key contact: Greg Tucker

Our expertise includes brewing science and microbial physiology, the breeding of improved crop strains that can promote optimal biofuel production and the science and technology of fuel utilization. Our team are developing a co-ordinated multi-disciplinary study of biofuel generation from brewers spent grains between the University and five industrial partners. In addition, our Food and Biofuel Innovation Centre has an area dedicated to biofuel and has equipment to develop new and efficient ways to turn waste and non-food agricultural products (e.g. wood and straw) into alcohol for use as fuel.

Biobutanol

Synthetic Biology Research Centre

Key contact: Nigel Minton

One of the research areas in the Synthetic Biology Research Centre is on the generation of liquid transportation fuels and other chemical commodities from renewables using microbial fermentation. Professor Minton’s research is especially relevant to the production of second generation biofuels, and in particular biobutanol. This is being achieved through the application of advanced gene technologies to improve both the yield of fuel by the process organism, as well as enhancing its ability to degrade lignocellulose.

Biomaterials: Products, Properties and Processing

Key contacts: Tim Foster, Chung Lim Law, Bettina Wolf

Understanding how food microstructure evolves during processing from ingredient to product and how it affects in-use characteristics plays an important role in the design of healthy safe-to-eat foods with good sensory properties. Our expertise encompasses processing and analysis of low moisture to high moisture products as well as lipid based foods such as spreads and chocolate.

Our processing and property analysis suite is available for use and includes thermomechanical extrusion, comminution, spray drying, retorting, thermal analysis techniques, spectroscopies, rheology, texture analysis, interfacial tension, particle size and wet chemistry. Research is conducted into the interplay between food or animal feed and the digestive system with respect to microstructure deconstruction following ingestion and its impact on sensory properties, energy and nutrient uptake – which in some instances is desired to be delayed. Microstructure design expertise includes interfaces in foam, emulsion and suspension based products; emulsions, suspensions and starch based products through processing with or without shear understanding hydration and plasticisation.

The Food Structure research theme performs fundamental and applied research into the creation, evaluation and understanding of the structure of foods, pharmaceutical systems and biomaterials. The main expertise of the Group is the creation and characterisation of biopolymer-based structures over a range of water contents, from solutions and gels to low moisture glassy systems, although more recently, it has developed substantial expertise in sugar and fat based confectionery systems and emulsions.

One of the strengths of the group is its extensive interaction with industry. This involves companies of different sizes (from SMEs to large multinationals) from different sectors (ingredients, food manufacturing, process equipment, analytical equipment, etc.). The Food Structure group also collaborates extensively internationally, most recently through the European Polysaccharide Network of Excellence which is committed to integrating polysaccharide research across the European Union. The group already has first class equipment for the physical characterisation of foods, ingredients and other biomaterials (see facilities) and this will be further strengthened through access to techniques residing with other partners in the Network.

Key contact: Rachel Gomes

Economic incentives are encouraging new approaches to manage manufacturing resources and treat wastes to enable reuse, recovery of value products and/or safe release into the environment. Processes where bio-sourced feedstocks or catalysts are used are of particular interest, where inherent variability of the bio-input increases the system complexity. Key research expertise includes: product analysis (including metabolite profiling) to inform process development and optimisation, understanding the impact of biomass variation on natural products extraction and processing, using process considerations to inform feedstock development, diversifying to the biorefinery concept, and obtaining value from waste streams (chemical and energy products).

Key contact: Chung Lim Law

The Food and Bioproduct Processing Centre is a joint UK/Malaysian campus venture, and focuses on processing foods and bioproducts including fruits and vegetables (salak, ciku, chempedak, durian, jackfruit, kiwi and papaya); herbal products (ganoderma and misai kuching); agricultural products (paddy and cocoa beans); biopolymers such as alginate as well as high value products such as edible bird’s nest. The Centre is currently collaborating in: assisting a noodle company, exploring new beauty and healthcare products derived from edible bird’s nests; assisting the Ministry of Health in formulating guidelines on safety and quality of edible bird’s nests.
Food and Drink Capability Statement

Brewing

Key contacts: David Cook, Joanne Hort, Chris Powell, David Quain

The University of Nottingham is a centre of excellence for brewing technologies delivering outstanding value, research and teaching to the brewing industry through internationally recognised excellence. Our scientists work with the brewing industry to meet the challenges of the 21st century; researching novel process developments targeted towards increased sustainability, efficient resource usage and minimising waste or effluents. The approach is truly multi-disciplinary, providing new solutions by bringing together expertise in crop science, malting, brewing, sensory and consumer science, engineering, novel materials and environmental science.

Based in the Bioenergy and Brewing Science Building, the centre houses brewing science laboratories which contain their own mini experimental brewery and also have access to international brewer SABMiller’s pilot plant which is co-located in the building. SABMiller uses its pilot plant to develop its own products and for research into the brewing process.

Bioproducts

Key contact: Anna Croft

Our general expertise is in biological oxidation and prevention. Oxidation can result in the accumulation of free radicals in the body which can cause adverse effects on lipids, proteins and DNA. Food components, such as phenolic compounds, act as antioxidants which can reduce free radical intermediates. Understanding antioxidation mechanisms of naturally occurring polyphenols (e.g. in Irish seaweed) and complementary combinations (polyphenol-proteins) is important in food formulation and in improving nutraceutical capacity. The team also specialise in the use of ionic liquids for extracting natural bioactives.

Biosensors

Key contact: Serhiy Korposh

The team is involved in the development of fibre optic chemical sensors with a functionalised sensitive layer to detect specific chemical compounds in liquids and in air. Specific applications of the work include detecting indoor/outdoor air contaminants, measuring bulk refractive index change of a liquid sample in real time, and in monitoring chemical and bio compound binding reactions and deposition.

Biotechnology


The work at The University of Nottingham in the area of biotechnology spans faculty structures but is focused on the state of the art developments in understanding the genetic origins of behaviours of and functional materials produced from plants and micro organisms. Such developments will be valuable in the pursuit of creating value-added materials from natural resources. Past work has focused on the area of second generation biofuels created from fermentation of materials from lignocellulosic origin, but this is being expanded into the production of valuable materials and chemicals from yeast and bacterial fermentations, and the use of plant genetics and breeding programmes for plants as chemical factories. Work also focuses on the development of novel ways to control and detect bacterial pathogens, creating new diagnostics and therapeutics.
Food and Drink Capability Statement

Chemical Sciences
Key contacts: Trevor Farren, Jonathan Hirst

The School of Chemistry is home to world-leading research, with 95% of our research activity judged to be 'internationally excellent' or 'world leading' (REF2014). The School has 44 academic staff, 60 post-doctoral researchers and over 150 PhD students and fosters numerous collaborations across the university with engineering, food science, physics, biosciences and medicine. Our research spans from natural product synthesis of bioactive chemical compounds through new materials for energy applications to the computational modelling of chemical systems.

Research related to food and drink has included sustainable approaches to processing and valorising biomass (see Sustainable Chemical and Biological Processing, page 26), understanding the chemical and physical mechanisms of aging processes in food and drink products and extraction of bioactive chemicals from crops. We also investigate methods of manufacturing new polymers and biomaterials and use spectroscopy and computational analysis to understand the behaviour of complex biomolecules including proteins (enzymes) and nucleic acids. The School is investing heavily into sustainable technologies, with its new Carbon Neutral Laboratory (see page 27) and the Centre for Doctoral Training in Sustainable Chemistry (see page 27).

The School of Chemistry collaborates with business from across the pharmaceutical, fine chemicals, food and energy industry sectors. Industry engagement and technology transfer are facilitated by the School’s integrated Business Partnership Unit, which comprises professionals from both academic and industrial backgrounds with an expertise in business and innovation.

Analytical Facilities within the School of Chemistry
The School of Chemistry possesses state-of-the-art analytical equipment for the analysis of small molecules, materials, surface science and study of biomolecules. Techniques available in our analytical suite include:

- Small molecule characterisation: nuclear magnetic resonance spectroscopy (NMR), mass spectrometry (MS), X-ray diffraction (XRD), elemental analysis, gas, liquid and ion chromatography.
- Bulk characterisation of the structure and material properties of solids, including polymers, microcrystalline powders or other materials: solid state NMR, powder XRD, thermogravimetric analysis (TGA), differential scanning calorimetry (DSC) and gel-permeation chromatography (GPC), rheology and viscometry.
- Surface chemistry and morphology of solids and liquids: X-ray photoelectron spectroscopy (XPS), scanning and transmission electron microscopy (SEM/TEM), atomic force microscopy (AFM), raman microscopy.
- Studies of biomolecules (proteins, peptides) and interactions with small molecules: high-field NMR, FT-ICR MS.

Fine Chemical Synthesis
Key contact: Anca Poreda
Expertise is in bio- and chemical catalysis. The group is looking into the development of novel and efficient catalysts for the sustainable synthesis of organic chemicals, by combining approaches from both chemical and enzymatic catalysis. We investigate the genetic and chemical modification of proteins, their characterisation and their functionality.

Sustainable Chemical and Biological Processing
Key contact: Steve Howdle
The sustainable chemical and biological processing priority group is a focal point for our world-leading research into new, green chemical, biological and engineering technologies. The team works together with the chemical-using industries to embed sustainability within manufacturing processes, minimise energy usage and adopt new types of renewable feedstocks and catalysts, including biocatalysts. Our aim is to transfer new technologies and approaches from academia into industry, in order to create real, global impacts. We work across a broad range of manufacturing sectors including pharmaceuticals, agrochemicals, energy and advanced materials, food science and FMCG, industrial biotechnology and synthetic biology and biofuels.

Our approach encompasses feasibility and precompetitive scoping projects through to more focused, near market opportunities and defining new supply chains. We welcome industrial partners across all manufacturing and chemical-using sectors to work on large-scale collaborative projects to help take sustainable concepts and ideas to commercial reality.

Skills in chemistry are relevant to industry, including cleaner chemical synthesis with novel and efficient catalysts as tools, leading to a wider range of accessible products and new materials. Sustainable Chemical Processing is also a major area that encompasses a broad range of activities and expertise across chemistry and chemical engineering, including hydrothermal synthesis and microwave processing. Supercritical carbon dioxide is used as a new solvent for polymer synthesis and materials processing. Current areas of interest focus upon new routes to polymer synthesis and nanostructured polymeric materials and also new approaches to tissue engineering and drug delivery.

Centre for Sustainable Chemistry: The Carbon Neutral Laboratory
Key contact: Pete Licence
The School is expanding with the construction of a new, iconic Carbon Neutral Laboratory (CNL). The building will meet the highest globally recognised standards in sustainable construction and operation and will be entirely carbon neutral over 25 years. The CNL will embed innovative features into its design to ensure it meets these targets, including solar panels, biowaste heating, low energy fumehoods and integrated water and energy management.

The CNL will host internationally excellent research into green and sustainable chemistry and will support industrial collaboration and science outreach and education. Those working in the CNL will redesign their research methods, leading to a new generation of world-leading chemists who have sustainability embedded into their thinking.

The CNL is being funded by generous donations from GlaxoSmithKline and the Wolfson Trust and a grant from the Higher Education Funding Council for England (HEFCE).

Centre for Doctoral Training in Sustainable Chemistry
Key contact: Chris Moody
The Carbon Neutral Laboratory (CNL) will be home to the new Centre for Doctoral Training (CDT) in Sustainable Chemistry. Over nine years, the CDT will train a new generation of innovative scientists and engineers in green and sustainable chemistry. Sustainable chemistry takes a holistic approach to chemical processes, seeking to maximise the use of renewable bio-feedstocks, reduce hazards, minimise energy usage and eliminate waste. Sustainable chemistry aims to make chemistry benign by design.

The focus of the CDT is on three key sectors where sustainable chemistry can add real value – pharmaceuticals, fine chemistry, food and drink and research programmes are being developed in collaboration with companies from each sector. Led by Chemistry, the CDT will bring together researchers in the School with experts in food science, process engineering, biotechnology and life cycle analysis.

Alongside their core research skills, CDT students will develop their professional and business competencies, with industry partners participating in the training programmes. Consequently, students will be equipped for a leading career in the chemical sciences or similar user community, with emphasis on the skill sets that are required for a more sustainable future.
Food and Drink Capability Statement

Comparative Medicine Group

Key contacts: Cinzia Allegrucci, Lisa Chakrabati, Malcolm Cobb, Paul Loughna, Nigel Morgan

The group aims to conduct hypothesis-driven, evidence-based research into spontaneous and induced disease in companion animals or relevant animal models. This is in order to explore the similarities or differences between veterinary and human medicine. There are four current research areas: Cancer Pathogenesis (Nigel Morgan, Cinzia Allegrucci); Cardiovascular Disease (Malcolm Cobb); Musculoskeletal Disease (Paul Loughna) and Age-related Disease (Paul Loughna, Lisa Chakrabati).

Corporate Social Responsibility

The International Centre for Corporate Social Responsibility (ICCSR)

Key contacts: Paul Caulfield, Wendy Chapley

The ICCSR was founded in 2002 and has established an international reputation for the quality of its teaching and academic research. The ICCSR team engages in mainstream teaching and research under the following broad headings: strategies for CSR; business ethics; social and environmental accountability; CSR and governance; managing for sustainability. It adopts an interdisciplinary approach and has an international focus. Specialist programmes available through the ICCSR include an MBA in CSR, an MSc in Sustainability, and a PhD programme. The ICCSR is also highly active in practitioner forums and work closely in dialogue with Business in the Community (BIC), Institute of Corporate Responsibility and Sustainability (ICRS), and United Nations Principles for Responsible Management Education (PRME). ICCSR team members are also active in a advisory capacity with a number of leading global businesses and national governments.

Edible Oils & Fats

Key contact: Sayed Azam-Ali, Sean Mayes

Crops for the Future (CFF) are a non-profit company focused on research into underutilised crops for food, feed, fuel and materials. CFF is a joint venture between The University of Nottingham and the Government of Malaysia. Founded with a US $42m grant that covers infrastructure and wage costs until 2018, CFF embeds multidisciplinary research (from genomics to socio-economics and policy) into the design of CFF research programmes. Six exemplar programmes have been established, focused on Food Security (Banyield), Fruits (BiomassPLUS), Aquaculture (FishPLUS) and Knowledge Systems (CropBASE) aiming to find new products and processes for minor and new crops species.

Digital Economy Research

Horizon

Key contact: Tom Rodden

Horizon is a Research Institute at The University of Nottingham engaged in Digital Economy Research which brings together researchers from a broad range of disciplines to investigate how digital technology may enhance the way we live, work, play and travel in the future.

Digital Energy Research

Established in 2009, this venture represents an initial £40m investment by Research Councils UK (RCUK), The University of Nottingham and over 100 academic and industrial partners; in both a Research Hub and Doctoral Training Centre within the RCUK Digital Economy programme.

Building on the Digital Britain plan, Horizon research focuses on the role of ‘always on, always with you’ ubiquitous computing technology. The aim of this venture is to investigate the technical developments needed if electronic information is to be controlled, managed and harnessed, with potential to develop new products and services for societal benefit.

Edible Oils & Fats

Key contact: David Gray

Our research centres on the general area of edible oil quality and seeks to explore novel ways of delivering healthy oils to foods, with minimum loss to oil quality and minimum impact on the environment. Oils and fats provide certain vitamins (e.g. vitamin E); contain polyunsaturated fatty acids (omega-3 and omega-6) that are converted in the body into molecules that control important activities (e.g. blood coagulation, blood pressure, membrane functions and reproduction); and carry desirable flavour molecules. When trying to improve the nutritional quality of a food product by increasing the amount of polyunsaturated fatty acids there is an increased risk of the development of off-flavours which must be minimised.

Energy Efficiency

Key contact: Mark Sumner

Research expertise in this group includes understanding and optimising electrical energy consumption for all processes – lighting, heating, and transport. Part of a wider power electronics group that has a strong background in all aspects of electrical energy conversion including ac-dc, dc-dc and dc-ac conversion, motor drive systems (hybrid, all-electric propulsion), operation of micro grids (on and off grid), use of energy storage to optimise use of renewable energy sources (cost, peak power reduction, CO2 reduction). The group has a strong track record of working with stakeholders to develop prototype solutions.

Key contact: Keith Baker, Dr Gerald Busca

The Environmental Technology Centre (Key Contacts Keith Baker, Dr Gerald Busca) offer support to SMEs in the areas of energy efficiency, resource efficiency and waste minimisation. There are a number of ways that the ETC can help a business, ranging from understanding how to use resources more efficiently, to improving water and energy management and identifying new technologies to make improvements to processes. Qualifying businesses can receive up to five days of funded consultancy.
Flavour Analysis

Key contact: Ian Fisk

Conventional flavour analyses focus on extracting, identifying and quantifying the volatile and non-volatile components of flavours using GC and LC techniques. This gives information on the flavour composition but does not represent the flavour profiles actually delivered to flavour receptors in the nose and mouth. Mastication and food structure cause significant changes in the release of both tastes and aromas, creating significant differences in sensory perception. This is one reason why correlations between flavour composition and flavour perception are difficult to establish. For this reason, we have investigated techniques that measure the flavour profiles close to the receptors as well as the way that the profiles change with the time of eating.

The online techniques have been used to study the generation of flavours during thermal processing as well as the release of pheromones from insects.

Food and Biomaterials Rheology

Key contacts: Davide Lo Presti, Bettina Wolf

Rheology deals with the deformation and flow of matter, especially the non-Newtonian flow of liquids and the plastic flow of solids. This branch of physics is important in the context of food and biomaterials processing as most processes involve some sort of flow or deformation of material. Examples include the factory based processes of pumping, dosing, and coating but also extend to oral processing and transport and mixing processes within the digestive tract. The rheological properties of foods and biomaterials are valuable for process and product design. They provide fundamental insights into the material’s microstructure as the rheological properties are a response to the application of flow and deformation to the product’s specific microstructure.

Rheology is a practical as well as a fundamental tool. The rheology labs across the University offer a wide range of expertise and knowledge of food processing and, in combination of these facilities in one building allows Quality Control laboratory and sensory analysis. The combination of two initiatives, part funded by the European Regional Development Fund and the Biotechnology and Biological Sciences Research Council, this centre houses the food production facility that has an extensive suite of facilities for: extrusion, bakery, retorting, as well as a development kitchen, Quality Control laboratory and sensory analysis. The combination of these facilities in one building allows the development of new products from conception to consumption.

The aim of the centre is to form a regional hub containing state-of-the-art measurement and processing equipment, expertise and knowledge of food processing and, in particular, lipids and starches. The centre provides a focal point to enable businesses engaged in all aspects of food manufacture to improve their understanding of starch and lipid ingredients and to optimise the production of commercial lipid-related products.

To retain a competitive edge it is imperative that companies embrace consumer pressures for: lipids and starches from sustainable sources; less chemically processed; natural anti-oxidants and emulsifiers; reducing fats in the diet. Demands for energy efficiency, waste reduction or reutilisation are forcing many businesses to re-evaluate their methods of manufacturing a range of products using oils and fats.

Food and Agricultural Ethics

Key contacts: Kate Millar, Pru Hobson-West

The Centre for Applied Bioethics (CAB), based across the School of Biosciences and School of Veterinary Medicine and Science (SVMS), focuses on research and training related to the social, legal and ethical issues raised in food and agricultural research and production.

Research capacity includes conducting research on specific themes such social dimensions of food technology assessment, food and biotechnology ethics, and the development and application of ethical frameworks to support decision-makers (e.g. policy and industrial sector). The group is also working with the European Commission’s conceptualisation of Responsible Research and Innovation (RRI) and how this might be operationalised in the food and agricultural sector. The Centre research group has experience in developing and conducting stakeholder participatory processes and applying qualitative social science research methods. Members of the Centre have a wide range of expertise and knowledge of food processing and, in particular, lipids and starches. The centre provides a focal point to enable businesses engaged in all aspects of food manufacture to improve their understanding of starch and lipid ingredients and to optimise the production of commercial lipid-related products.

The lipid and starch centre:

• Establishes links between companies thereby establishing a robust supply chain in the area of starch and lipid processing.
• Provides a hub (equipment, scientific expertise and training related to the social, legal and ethical issues raised in food and agricultural research and production). The technical support to assist in the implementation of the changes in lipid use for these multi-sector companies and for the smaller specialised companies is limited.
• Delivers recommendations for process scale up.
• Facilitates close working links between students and industry for mutual benefit.
• Establishes links between companies thereby establishing a robust supply chain in the area of starch and lipid processing.

An essential feature of the centre is that it incorporates equipment within three tiers: processing equipment, quality control instrumentation and analytical research instrumentation. At all three stages we have the ability to deliver at the correct level from basic processing though to fundamental measurement.
Geomechanics

Key contact: Hai-Sui Yu

Physical compositions of soils can affect plant growth. Hence work in soil mechanics is crucial in understanding deformations in soil structure and in characterising fluid flow within soil structures. Our expertise includes micro and macro modelling of multi-phase soil structures and their interaction with fluid and plant.

Geospatial Positioning for Farming, Precision Agriculture and Global Food Security

Key contacts: Suchith Anand, Alan Dodson, Chris Hill, Stuart Marsh, Xiaolin Meng, Terry Moore

The team is researching satellite navigation and positioning systems, photogrammetry, remote sensing, sensor integration, integration of large data sets/images, geoinformatics and data modelling, geospatial intelligence, location based services, semantics, reasoning and cognition. New perspectives on food security and agricultural species diversity with respect to location are being explored by the integration and modelling of a wide range of geospatial resources (e.g. climate records, ground condition, crop traits etc…) in a “geospatially orientated database”. Geolocation based plant breeding in concert with integrated workflow modelling will greatly support global food security.

In collaboration with the Animal Sciences Division of the School of Biosciences, new radio-based ranging systems, data fusion algorithms and effective sensor integration are also being used to track and characterise cow mounting behaviour to detect oestrus and optimise insemination.

Geospatial Science

Nottingham Geospatial Institute

Key contact: Mike Jackson

The Geospatial Science group engages in all areas of geoinformatics research, resulting in collaborations across many disciplines and institutions. Research is undertaken in both long term fundamental challenges and shorter term applications-orientated issues and is global in scope. It has experienced strong growth since its launch, building an international reputation for research excellence. In 2009 we were designated an ‘Oracle Spatial Centre of Excellence’.

Our current research is focused on these sub-themes:

- Spatial Data Infrastructures (SDI)
- Geospatial Intelligence (GI or GEOINT)
- Interoperability and Standards
- Location Based Services (LBS)
- Semantics, Reasoning and Cognition
- Geoinformatics and Data Modelling
- Open Source Geospatial Research
- Geo Health Informatics Research.
Genomics

Key contacts: Graham Seymour, Sean Mayes, Ian King

The University of Nottingham’s researchers originally pioneered the use of transgenic technologies and gene silencing to create the first GM product for sale in Europe. Professor Graham Seymour is among a group of over 500 scientists from 14 countries, who form the Tomato Genome Consortium, which has sequenced the genomes of the domesticated tomato. These advances will help breeders to deliver fruits with improved taste and higher concentrations of nutrients and with better resistance to biotic and abiotic stresses.

The application of molecular genetics to understand crop trait inheritance and then to introduce desirable traits via marker assisted selection allows the development of tailored crop types for future environmentally-friendly production, processing and nutritional needs. Wheat, oil palm and tomato are a few of the crops being researched. Coupling the power of genomics with the ability to deliver the newly determined traits into crops via marker-assisted selection will reduce agricultural inputs, increase sustainability and crop resilience and produce raw materials for new products.

Global Food Security

Key contacts: Sayed Azam-Ali, Jerry Roberts

Food production is an essential element of the world we live in and in the near future will be of increasing significance. Climate change, growing population and scarcity of resources will demand novel approaches to growth of both plant and animal-based foodstuffs. Our research interests utilise expertise in molecular biology, crop physiology and crop breeding and lie both in optimising the nutritional quality of plant foods and the use of plants as a bioenergy source. Our knowledge of animal nutrition, lactation, muscle and adipose tissue biology, and digestive efficiency is directed towards enhancing the performance and feed efficiency of livestock and controlling factors such as meat tenderness, milk fatty acid profile and environmental emissions. Research themes within the Global Food Security Research Priority Group include: waste, distribution and production, societal impact, climate change and environmental impact, governance and policy. It has strong links with the Centre for Globalisation and Economic Policy which has branches in Nottingham, Malaysia and China and which undertakes research on the effects of global trade barriers and agricultural economies.

Granular Material Behaviour

Key contacts: Paul Langston, Xia Li

Understanding the particle-scale and continuum scale mechanics of granular materials is important for numerous industries including food.

Modelling the flow of granular material can be done using Discrete Element Method (DEM) which uses numerical integration to solve the dynamics of elements from the forces acting on them over small time intervals. Characterisation of granular flow phenomena is important in predicting powder behaviour and handling during storage and conveying. Recent applications of DEM have concentrated on modelling non-spherical particles including high aspect flexible fibre packing, which could be important in the development of synthetic meat products.
Human Factors in Manufacturing

**Key contacts:** Glyn Lawson, Sarah Sharples

Our research focuses on optimising human involvement in production processes. This can be achieved through appropriate use of virtual reality technologies for training and factory design. Training with virtual reality offers advantages such as improved training efficiency, greater engagement and motivation, ability to train before the factory line has been built. For factory design, virtual reality can support ergonomic design at an early stage in the development process, reducing the costs associated with late changes.

Human Factors in User Behaviour and Diet

**Key contacts:** Sarah Atkinson, Alexandra Lang

Human factors are experienced throughout the product design cycle and in evaluation of interventions for usability, acceptance and impact. The team are researching the implementation of new technology for healthcare interventions and behaviour change. This includes understanding behaviour around healthy and unhealthy eating to design appropriate technology for improving food and drink choices, the use of technology as a communication tool for behaviour change (patients and clinicians’ native users and experts) and novel innovation to improve food and drink choices in specialist populations.

In-body Imaging of Food and Drink

**Key contacts:** Guru Aithal, Sue Francis, Penny Gowland, Dileep Lobo, Luca Mariani, Peter Morris, Gordon Moran, Robin Spiller

A long standing collaboration between the Nottingham Digestive Diseases Centre with its NIHR-funded Biomedical Research Unit and the Sir Peter Mansfield Magnetic Resonance Centre specializes in imaging gastrointestinal function and the physiological response to food and drinks in humans. This includes non invasive, in-body imaging of the fate of foods and drinks in the gastrointestinal tract, organ function, mechanisms of satiety, gut peptides response to nutrients, blood flow, liver function, magnetic resonance spectroscopy (MRS) of liver fat and hepatic energy metabolites and interactions between the gut and the brain including fMRI of taste, aroma, and oral fat. We have several state-of-the-art, fully research dedicated MRI scanners. Examples of past industrial collaborations include imaging intragastric gelation of alginates, effect of cholesterol-lowering yogurts on gallbladder contraction and effect of fat emulsions microstructure on satiety.

Industrial and Biomedical Macromolecules

**The National Centre for Macromolecular Hydrodynamics**

**Key contacts:** Gary Adams (Insulin Research); Stephen Harding (Physical Biochemistry & Glycobiology); David Scott (Physical Biochemistry & Archae)

The Centre is a facility for the characterisation of the sizes, shapes and interactions of macromolecules of biomedical and industrial importance (proteins, polysaccharides, DNA, synthetic polymers etc.) in solution. Research is focused into the following areas:

- Crystallohydrodynamics (combining high resolution crystallographic information with solution data for elucidating the solution conformation of molecular assemblies, with particular reference to antibodies)
- Therapeutic Polysaccharides (relating solution structure and interactions with bioactivity and mucoadhesion)
- Macromolecular Stability (with particular reference to industrial preparations of antibodies and polysaccharides)
- Archaea (a distinct domain of life ranked equally with the bacteria and the eukaryotes – we are trying to gain an understanding of the fundamental molecular biology and physical chemistry underpinning these fascinating microorganisms)
- Insulin Delivery (using a detailed knowledge of its physico-chemical interactions to help develop a self-regulating insulin delivery route for the treatment of diabetes).
Food and Drink Capability Statement

Industrial Microwave Processing
The National Centre for Industrial Microwave Processing (UK)
Key contact: Sam Kingman

The Industrial Microwave Processing Research Group (NCIMP) is led by Professor Sam Kingman and is a part of the Energy and Sustainability Research Division, in the Faculty of Engineering at The University of Nottingham. The NCIMP, the largest group of its type in the world conducts multi-disciplinary research, development and commercialisation studies into microwave heating technologies which deliver economic and technical benefits across fields as diverse as food, fuels, mineral processing, pharmaceuticals and recycling. It has developed significant research expertise in microwave processing for applications in the food sector. Particular areas of interest in this sector include a resource efficient food manufacturing supply chain (energy and water; waste minimisation; manufacturing of the future); food safety (e.g. sterilisation) and smarter packaging. The NCIMP focuses on the interaction of microwaves with materials and in the scale-up of microwave heating processes. To date the NCIMP has led teams to successfully scale and license four industrial microwave technologies in the fields of industrial minerals, oil and gas and mining.

The NCIMP has led and participated in a wide portfolio of research grants from research councils, industrial institutions, Innovate UK, DEFRA, European Union and Industry, produced over 100 papers in peer-reviewed journals together with more than 10 patents and contributed to numerous industry publications. The NCIMP currently supports a research portfolio of approximately £15m and comprises ca. 45 multidisciplinary researchers working on a wide range of highly multi-disciplinary research, development and commercialisation projects in the field of industrial microwave processing. It has unique equipment for dielectric property measurements, an extensive selection of laboratory scale microwave and RF systems and a pilot scale facility containing hardware capable of delivering over 400kW of microwave power at 896MHz and 60kW at 2.45GHz.

Innovative Manufacturing in Food
EPSRC Centre for Innovative Manufacturing (CIM) in Food
Key contacts: Tim Foster, David Gray, Bettina Wolf (in collaboration with the Formulation Engineering Centre, University of Birmingham – Professor Ian Norton, and the Centre for Sustainable Manufacturing, Recycling and Re-use Technologies – SMART, Loughborough University – Professor Shahin Rahimifard).

The Centre’s objectives are to meet the current and future needs of the Food Manufacturing Industry, tackling issues in the four main areas of global need: a) Global food security - providing manufacturing capability for conversion of (under utilised) crops; b) health enabling food structures to be manufactured with nutritional value and optimised nutrient delivery; c) sustainable production – reduced energy and water requirements including, reduce / re-use waste (for valorisation into new materials), and d) evaluate supply chain and business models to maximise the efficiency of food production and supply using advanced manufacturing strategies e.g. Flexible and distributed manufacture.

This will be achieved by focusing on two specific Grand Challenges (GC): 1) Innovative materials, products and processes and 2) Sustainable food supply and manufacture. The Grand Challenges incorporate multi-disciplinary technical input from process engineering, chemical engineering, material science, food science, microbiology and toxicology, life cycle analysis, ICT and advanced manufacturing, and spanning the manufacturing paradigm from the technology / process level through to production and supply chain level.

The connection to industry through support, involvement in the advisory board and links to SME networks, through an interaction with the Manufacturing Technology Centre and clear alignment with the Innovative UK High Value Manufacturing Strategy 2012-2015 will provide exploitation routes for the developments within the Centre. This should provide funding routes for sustainability beyond the first five years EPSRC funding (£5.5m spent on research).
Magnetic Resonance Imaging
Sir Peter Mansfield Magnetic Resonance Centre
Key contacts: Peter Morris, Penny Gowland, Sue Francis, Luca Marciani, Joanne Hort

The Sir Peter Mansfield Magnetic Resonance Centre (SPMMRC) is part of the School of Physics and Astronomy. It has been conducting research into Magnetic Resonance Imaging (MRI) since Sir Peter Mansfield’s pioneering work in the early 1970s and is now one of the largest, physics-based MRI research centres in the world. The SPMMRC comprises seven academic staff, 18 research staff and 33 PhD students, with a current grant portfolio of more than £10m, and sustained University investment. Biomedical imaging is one of the University’s key Strategic Priorities.

The SPMMRC houses Philips 1.5T, 3T and 7T MRI human scanners MR-compatible electroencephalography (EEG) kit and a CTF magnetoencephalography (MEG) scanner, and 3.4T and 9.4T vertical magnets with a range of capabilities from dynamic nuclear polarisation to microimaging.

The SPMMRC, in a long standing collaboration with the Nottingham Digestive Diseases Centre, has been instrumental in developing MRI of gastrointestinal function and in-body imaging of foods. Work carried out with industrial support has investigated the physiological response to fat emulsions, intragastric behaviour of hydrocolloids, performance of meal replacement shakes and mode of action of dairy-based, stanol-containing drinks.

Pioneering work at the SPMMRC developed methods to monitor the body’s energy stores using non-invasive spectroscopic techniques. This research monitored the response to feeding of hepatic and muscle glycogen and lipid stores in health and disease.

The SPMMRC also has a major, on-going programme in the development of functional neuroimaging to improve understanding of the neural response to foods. This includes a BBSRC Industrial Partnership Award grant in collaboration with the Sensory Science Centre and a major food manufacturer which carried out pioneering work applying MRI to study the impact of fat on flavour perception, linking behavioural and cortical response. A second BBSRC IPA grant project, again in collaboration with the Sensory Science Centre and industry, aims to form a gustotopic map and understand the phenomenon of thermal taster status.

Mathematical Modelling
Centre for Mathematical Medicine and Biology
Key contacts: Ian Dryden, John King, Markus Owen, Jonathan Wattis, Andy Wood

The Centre for Mathematical Medicine and Biology (CMMB) is based within the School of Mathematical Sciences and comprises of members of The University of Nottingham who use mathematical methods to provide insights into biological and biomedical phenomena. We aim to promote the application of mathematical modelling to medicine and the biomedical sciences, and to stimulate multi-disciplinary research within the University and beyond. In particular, work is being undertaken in the area of food science, in collaboration with members of e.g. Centre for Plant Integrative Biology and the School of Veterinary Medicine and Science.
Food and Drink Capability Statement

Microbiology and Food Safety

**Key contacts:** Ian Connerton, Christine Dodd, Ian Fisk, Ken Mellitis, Cath Rees

Research interests include the investigations of the roles of micro-organisms in foodborne disease, food production practices and spoilage. There is a wide expertise base in our research team, with experience of working with bacteria, fungi and viruses associated with food and beverage production. The University of Nottingham plays a major role in a £4m cross-disciplinary, multidisciplinary, nationwide study on Campylobacter which is the leading cause of food poisoning in the UK.

A common theme is the survival and adaptive responses of micro-organisms to environmental stresses. These include how the environmental cycling of micro-organisms can influence the micro-flora of farm produce, and the colonisation of livestock. Post-ferm stage of particular interest are the inimical processes imposed under food processing and preservation regimes, and how these will modify the interaction and survival of micro-flora within food products, packaging materials and on plant infrastructure for factory operations. Such information can be used to formulate micro-biological risk assessments and is key to the development of hazard analysis critical control points (HACCP) for food production processes.

Research directed at new approaches for product decontamination are another common theme within the Group through the use of novel physical methods and the development of biocontrol agents, such as bacteriophage and bacteriocins, that are directed specifically to exclude unwanted micro-flora from the food chain.

Probiotics are live microorganisms thought to be beneficial to humans by restoring the balance of microflora in the digestive tract. One project funded by the Food and Drink Net investigates the optimum way of carrying out probiotics in the digestive tract. Another project is directed at assessing the use of probiotics in the infant diet.

Nanoscience

**Nottingham Nanotechnology and Nanoscience Centre (NNNC)**

**Key contact:** Andrei Khodopyan

The Nottingham Nanotechnology and Nanoscience Centre (NNNC) is a cross-Faculty interdisciplinary research centre at The University of Nottingham. The Centre is currently supported by the Schools of Chemistry, Pharmacy, Physics & Astronomy and the faculty of Engineering. The centre provides a unique opportunity to undertake research in the Centre for all University researchers and external researchers, including industrial companies. The access is supported by highly qualified research officers who run the instrumentation and assist with specimen preparation, structural characterisation and chemical analysis, and data interpretation. In addition all research officers are actively leading developments of new methods, such as cryo sample preparation, manipulation and electron microscopy analysis, in situ transmission electron microscopy and tomography experiments, ultra-sensitive energy dispersive X-ray analysis and X-ray photoelectron spectroscopy of liquid materials, putting the NNFC at the forefront of international research.

**Instrumentation available in the NNFC:**

- **Field Emission Gun Transmission Electron Microscope** (FEG-TEM) equipped with EELS and EDX spectroscopy detectors, tomography, heated and cryo specimen stages for in situ experiments.
- **Focused Ion Beam Scanning Electron Microscope** (FIB-SEM) equipped with EDS detector and cryo capabilities.
- **X-ray Photoelectron Spectrometer** (Kraus Analytical Ultra XPS).
- **Raman spectrometer/microscope** with different lasers and heated/cryo specimen stages.
- **Particle sizing equipment** (NanoSight nanoparticle tracking, dynamic light scattering, and ZONE particle analyser).
- **Specimen preparation laboratory equipped with cryo microtome, cryo plunge and cryo transfer system**.

**Model Plants**

**European Arabidopsis Stock Centre**

**Key contact:** Sean May

At the European Arabidopsis Stock Centre, the University’s plant scientists are at the forefront of international research: studying the model plant Arabidopsis thaliana and tomato. They have identified several of the key genes that regulate their development, coordinating their genome sequencing efforts and providing underpinning resources to the international scientific community that have fuelled the recent impressive advances in our knowledge about fundamental plant processes.

Although most of the Arabidopsis stocks are used by research institutions and academia, both energy and chemical industries use model plants in the development of alternative energy crops and as a mechanism for monitoring the effects of pesticides and fertilizers.

Food and Drink Capability Statement

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**Types of food products previously studied in the NNFC:**

- Cheese, chewing gum, mushroom, plant based fibres and gels (sea weed and cellulose), bread, muffins, vegetable oil based emulsions, sorghum (a type of grain), seeds (sunflower etc.), arabidopsis, beer and yeast, starchy cereals (from potato, rice, wheat etc.).

Nutrition, Diet and Health


Internationally recognised translational research which focuses on the identification of nutrition and diet related factors that contribute to understanding how health and wellbeing can be improved across and between, stages of life in the life cycle. A proven multidisciplinary approach is exemplified by collaborations across the University (e.g. the Schools of Life Sciences, Medicine, Biosciences and the Centre for Mathematical Medicine and Biology, and externally (e.g. MRC/ARUK Centre for Musculoskeletal Ageing Research and the University of Nottingham and University of Birmingham). State-of-the-art, in house laboratory facilities, (e.g. the David Greenfield Human Physiology Unit, The University of Nottingham Derby Medical School site, the Division of Nutritional Sciences, and the Nottingham Digestive Diseases Biomedical Research Unit) enable investigation of the mechanistic basis of human disease processes using cellular to whole body techniques including energy expenditure and substrate utilisation measurement, body composition, imaging and spectroscopy (e.g. the Sir Peter Mansfield Magnetic Resonance Centre at Nottingham). Stable isotope tracers, biochemical techniques (e.g. intermediary metabolism (MRM) and molecular approaches (e.g. nutrient gene interactions, analysis of genes and proteins regulating muscle size including low-density array card analysis by an ABI HT7900 qPCR machine) are also key. Dietary intake, knowledge and behaviour patterns can be estimated and psychosocial influences on food choice and dietary behaviour explored, drawn on expertise in health psychology, dietetics and public health nutrition.

Research projects include understanding behaviour around healthy and unhealthy eating to design appropriate technology for improving food and drink choices, the use of technology as a communication tool for behaviour change (patients and clinicians/ naïve users and experts), novel innovation to improve food and drink choices in specialist populations and investigating the metabolic responses of consumers to functional foods, nutraceuticals and dietary supplements. In addition to acute, well controlled dietary studies based in the laboratory, strong links with clinical colleagues and the wider community facilitate longer term intervention and observational studies in a broad range of locations (e.g. Nottingham University Hospitals Trust, Sure Start centres, schools and in the work place). Current key areas of interest, that utilise fully integrated qualitative and quantitative techniques, include addressing the current multiple (and closely interrelated) challenges of firstly, the global increases in the prevalence of obesity and associated metabolic diseases (such as cardio vascular disease (CVD) and type 2 diabetes), and secondly, an ageing population. Throughout our work ethical guidelines are adhered to.
Resources. There is extensive collaboration between these thematic areas, with other Divisions / Schools within the University and with external academic and commercial organizations.

Experts at The University of Nottingham, working in collaboration with the University of California Riverside and Rothamsted Research UK have identified the molecular mechanism which plants use to sense low oxygen levels. The discovery could lead to the production of high-yield, flood-tolerant crops benefiting farmers, markets and consumers across the globe.

**Post-harvest Biotechnology**

**Key contact:** Asgar Ali

The Centre of Excellence for Post-harvest Biotechnology is a joint venture between the UK and Malaysian campuses which investigates the most innovative technologies and approaches for post-harvest preservation of fresh fruits and vegetables, and methods for prolonging the shelf life of fresh produce. The centre’s activities include: post-harvest physiology and biochemistry; microbiology and pathology of horticultural produce; phytochemicals from fresh fruits and vegetables to improve nutrition and human health; the use of nanotechnology in post-harvest activities; modified atmosphere packaging technology; horticultural produce post-harvest quality and shelf-life.

**Process Monitoring**

**Key contact:** Nik Watson

Expertise is in the development of novel ultrasound techniques for online non-destructive monitoring during food manufacturing. These techniques can be used to optimize food production and minimise waste. Experimental systems have been developed using state of the art non-contact ultrasound technology. This is required for the food industry to prevent contaminations. The design of monitoring systems are supported by multiphysics modelling of the physical changes the food materials experience during processing. This combined experimental and modelling approach develops a greater understanding of the process and improves the capability of the inspection system. Applications include the detection of foreign bodies in solid food manufacturing and monitoring of the frying process.

**Reproductive Biology**

**Key contacts:** Gary England, Kevin Sinclair

Research in the Division of Animal Sciences (School of Biosciences), and in the School of Veterinary Medicine and Sciences encompasses a range of complementary projects designed to investigate: fertility in dairy cows, environmental and nutritional influences on reproductive function across species (sheep, cattle, dogs, humans) and intra-uterine interactions during early pregnancy; effects of environmental chemicals on gonadal development and function; fetal programming of adult disease and dysfunction. Technologies include: post-genomic gene expression analysis including epigenetics; localisation of genes and gene products; implant and primary cell culture; cellular and whole animal imaging and whole animal in-vivo physiology.
The Rural Business Research Unit (RBRU) undertakes a wide range of economic, management and environmental assessment studies including the DEFRA Farm Business Survey (FBS). Much of the data is used to generate and support policy developments at national and European Union level. The data forms the basis of research projects that examine efficiency and performance variation in the agriculture and horticulture sectors, estimating relative performance and identifying key managerial actions and associated characteristics associated with high and low performance. These analyse and demonstrate the breadth of performance that exists across farms and enterprises.

The RBRU, as lead unit of Rural Business Research (RBR), is ideally placed to undertake further research programmes that can add value to the FBS data, through the collection, analysis and interpretation of additional enterprise and farm level data.

A key part of the role of RBR is to ensure effective knowledge transfer mechanisms are in place and are utilised via making the FBS data available on-line to farmers and advisors to aid business comparative analysis via business benchmarking tools. The FBS data also provides an immensely valuable research resource for undergraduates and postgraduates.

### Rural and Environmental Science

**Key contacts:** Neil Crout, Stephen Ramsden, Debbie Sparkes, Paul Wilson

Rural Efficiency, Economics and Risk Management

This research group provides policy-relevant data and analyses to enable increased understanding of the key performance drivers affecting efficiency, performance and stability of rural businesses and agri-food firms. The group draws upon data derived from the Farm Business Survey (FBS) and associated additional primary data relating to farm-level energy usage, environmental activities, water practices and business management activities; these large scale surveys are supplemented by in-depth case-study or postal survey approaches. Applied econometric and farm-level mathematical modelling techniques and expertise are the key analytical approaches utilised within the group.

### Farm Systems Assessment of Bioenergy

Bioenergy research integrates with the wider biofuel research within the University and in collaboration with external universities and research organisations, to examine the farm-level issues and potential for biomass production from UK agriculture, and additionally the impacts of bioenergy production in developing countries. Bio-economic modelling approaches draw upon primary and secondary data sources. The group also draws upon expertise in field crop experimentation and associated analysis in addition to expertise in the design, implementation and analysis of farmer surveys.

### Agricultural and Environmental Systems Analysis

We aim to improve our understanding of agri-environmental systems, including the management and policy interventions that can influence these systems. To achieve this, representative surveys are conducted and models constructed; these models are designed to capture trade-offs within the under-lying systems with particular emphasis on the mitigation of negative externalities (greenhouse gases, nitrate loss, ecotoxicity) and resulting trade-offs from different mitigation measures. Systems analysis draws upon primary and secondary data sources. Modelling expertise is provided within the group and the wider research community within the School of Biosciences.
Surface and Nanoscale Analysis of Food and Packaging Materials

Laboratory of Biophysics and Surface Analysis (LBSA)
Key contacts: Morgan Alexander, Clive Roberts, David Scurr

Extensive experience of supporting the development of academic and industrial formulation and packaging solutions across a range of disciplines including food and drink. World class analytical facilities and expertise in surface and depth profiling chemical, spectroscopic and mass spectrometry analysis aligned with nanoscale quantitative imaging and mechanical analysis through a range of state-of-the-art scanning probes microscopes. This capability allows a rapid multi-parametric breakdown of material properties and interactions at the micro and nanoscale, facilitating increased understanding of food properties and structure. Examples of previous studies include the resolution of industrial sticking problems in confectionary, identification of food packaging barrier properties and profiling the release of compounds from processed teas.

Sustainable Crops
Centre for Sustainable Crops
Key contact: Festo Massawe

The Centre for Sustainable Crops is a joint UK and Malaysian campus venture which focuses on both major and under-utilised food crops to generate knowledge that will contribute to improving the sustainability of food crop production. Alongside plant and crop physiology, a great deal of our research is committed to crop and molecular genetics and breeding. Topics include: molecular genetic analysis and crop improvement; plant-pathogen interactions; plant and fungal genetics; photosynthesis research; resource use efficiency; mass production of selected plants using tissue culture technology; control and expression of morphogenesis in the cloning of plants; development of vaccines in plant systems; abiotic stress research (specifically drought resistance traits in crop plants) and antioxidant properties in crops.

Flavour perception is affected by many factors including complex interactions between visual clues, taste, aroma, appearance, mouthfeel, and sound. The focus of research at The University of Nottingham is the development and combination of sensory and instrumental techniques to further our understanding of sensory perception and multi modal interactions whilst also considering inter-individual differences.

Such differences can occur due to differences in culture and hence prior exposure, whilst others are a result of genetic and other physiological differences in the individual. Emotional response to sensory properties of food products also has a significant role in determining product consumption and we have considerable expertise in this emerging area.

Understanding perception not only involves sensory science but draws upon other disciplines such as cognitive psychology, imaging, aroma chemistry and gastroenterology and we have strong collaborations with these groups in the University. A key part of our research is inclusion of cognitive neuroscience expertise and brain MRI techniques to map sensory perception and study many aspects of gastrointestinal (GI) function. We have combined sensory and analytical approaches to understand the contribution of different stimuli to flavour perception both in vitro and in vivo. We have studied cross-modal interactions in a range of systems and the effect of fat on flavour perception. We are now using high resolution fMRI to understand taste representation in the brain. We have also developed consumer relevant methods for the assessment of emotional response to food and beverages.

Sensory Science Centre
Key contacts: Joanne Hort, Louise Hewson

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Synthetic Biology

Synthetic Biology Research Centre
Key contacts: Alan Burbidge, Nigel Minton

The University of Nottingham has been awarded a £14.3m grant to create a new Synthetic Biology Research Centre (SBRC). The SBRC-Nottingham will use a synthetic biology approach to develop microorganisms that can make the chemicals and fuels that our modern society needs. A key focus for the SBRC-Nottingham is to demonstrate that we can break our reliance on fossil fuel and make chemicals and biofuels in a sustainable, cleaner and greener way. These organisms will convert simple gases, such as carbon dioxide and carbon monoxide into valuable chemicals. Carbon monoxide in particular is a waste gas from many industries such as steel mills. It can also be produced by converting waste biomass e.g. from the forestry and agriculture industries into “syngas”. By using waste biomass and greenhouse gases we aim to remove competition between fuel and food production and open the way to having positive impacts on climate change.

University Farm

Key contact: Stephen Ramsden

The University Farm has 445 hectares (1100 acres) of land, across three sites (Sutton Bonington, Bunny and Beeston) a herd of high-yielding Holstein dairy cows (approximately 200 cows yielding 10,500 litres per year, robotically milked) and a small flock of sheep (80 ewes). Within constraints and protocols imposed by its role as a provider of research and teaching resources, the farm operates commercially: currently, circa two million litres of milk per year is sold through a contract with Arla (owner of the Anchor and Lurpak brands), to provide liquid milk for Tesco. Crops are sold through Frontier Agriculture (jointly owned by Associated British Foods and Cargill plc) at their Edwalton site on the southern edge of Nottingham. Through a Service Level Agreement, the farm provides research, teaching and KT facilities for the two Sutton Bonington schools: Biosciences and Veterinary and Medical Science.

Research at the farm is based around four areas: crops, livestock, environment and engineering, although in many cases there is considerable interdisciplinarity (e.g. research based around farm waste products involves environmentalists, engineers, geographers, microbiologists and modellers).

Recent research projects in each area include:

- Measurement of greenhouse gas emissions (methane) from dairy cows; manipulation of diets to reduce emissions.
- Resource use efficiency in ancient cereals and their potential for providing genetic diversity in modern wheat varieties.
- Veterinary treatments and their effects on invertebrate species living in cattle pastures.
- ‘Profit from waste’: anaerobic digestion, microbial fuel cells, production of biogas energy.

In this latter category, a prototype Microbial Fuel Cell, originally KTP funded, is being tested at the farm in a joint project between the School of Engineering, Lindhurst Engineering and University Farm.

The Farm can be thought of as a laboratory, where research can be conducted across a range of different academic disciplines and as a system – with strong links to the food supply chain – which brings together these different disciplines. This is particularly useful in interdisciplinary research bids e.g. the EPSRC’s recent (2014) ‘Bridging the Gaps between the Engineering and Physical Sciences and Antimicrobial Resistance’ initiative.

Veterinary Science

Key contact: Gary England

Opened in 2006, the School of Veterinary Medicine and Science has established itself as a centre of excellence in both pure and applied research in whole animal biology in line with the overall aims of integrating veterinary biological research within the other relevant schools at The University of Nottingham. The School conducts research that is relevant not only to the wider veterinary, biomedical and bioscientific community, but also to local consumers of biotechnology and veterinary services. The School achieves excellence in research within the two themes of (i) Reproduction and Integrated Food Chain Research [NB the school has an on-site abattoir] and (ii) Comparative Medicine - the use of animals as models for human disease.

Within the two overarching research themes the School has strengths within the following main areas:

- Animal Nutrition
- Animal infection and immunity
- Comparative medicine
- Population health and welfare
- Reproductive biology
- Veterinary educational research.
**Food and Drink Capability Statement**

**Whole Systems Analysis**

**Key contact:** Jon McKechnie

Expertise is in taking a multi-disciplinary, “whole-system approach” to biomass-derived fuels and materials. On-going work assesses sustainable biomass supply chains, conversion technologies, and chemicals/plastics production from biomass sources. The whole-systems approach is also applied to research in non-bioenergy fields including: carbon fibre composites recycling; critical materials; microgrids and energy storage systems; and heavy-duty vehicle fuels.

**3D Imaging through X-rays (MicroCT)**

**Hounsfield Facility: 3D Imaging through X-rays**

**Key contacts:** Sacha Mooney, Craig Sturrock

A world leading multidisciplinary centre which uses state-of-the-art x-ray micro-tomography equipment to visualise and quantify the internal microstructures of an object in 3D. Through using the latest equipment, we are able to acquire images at high pixel resolutions down to <1µm without altering or destroying the sample.

A range of food products can be analysed ranging from snack bars to deserts. The technology can be used for:

- Detecting defects.
- Optimising a manufacturing process in order to reduce costs whilst maintaining quality.
- Food quality could be explored in 3D, visually and quantitatively, studying characteristics such as:
  - Porosity e.g. to investigate food texture.
  - Macro and Microstructure (for structural and mechanical properties, e.g. deformation, fracture, homogeneity).
  - Distribution and size of particles such as salts.
  - The 3D location and morphology of different ingredients.

Features and benefits:

The technique has a number of advantages over current methods of analysis such as optical and electron microscopy:

- Food products can be investigated in their natural state at atmospheric pressure and temperature. Other methods such as electron microscopy require a vacuum and coating of the sample.
- Microscopy requires the product to be cross-sectioned into thin slices. Even the most careful preparation can have destructive effects on the product. In contrast, x-ray tomography can visualise the internal structure in 3D without any cross-sectioning or preparation. Reliable 2D and 3D information can then be derived from the data.
- Microscopy is restricted to analysing small sections of the overall product. A large number of repeats are required in order to give statistically relevant results. With x-ray tomography, the entire product can be imaged and analysed, reducing the number of repeats that are needed.
- X-ray tomography data can be acquired at relatively high spatial resolutions ranging from <1µm to 500µm depending on the product’s size.
Training and Continuing Professional Development

The University of Nottingham is able to provide a range of training solutions for food and drink industry professionals across the extent of the University's expertise in the UK, China, and Malaysia.

Combining the world-class research of Nottingham's academics and their teaching capacity, the University is also able to provide bespoke or open professional development courses tailored to the needs of industry.

The University has specific resource within its Business Engagement and Innovation Services team dedicated to the development of training and professional development courses for industry professionals and you can find out more about the team by visiting their website, www.nottingham.ac.uk/cpd or contact the team on cpd@nottingham.ac.uk.

The University of Nottingham has extensive experience in training Agricultural, Food Industry and Health related professionals in part-time and distance-learning courses that are flexible and accessible and may be taken as stand-alone Continuing Professional Development or, in many cases, as part of accredited Postgraduate award.

One such specialist training programme, specifically designed for industry-related Continuing Professional Development, is the BBSRC AgriFood Advanced Training Partnership. Course titles and study modes centres are detailed in Appendix B.

BBSRC AgriFood Advanced Training Partnership
Key contacts: Deborah Kendale, Debbie Sparkes

The School of Biosciences at The University of Nottingham is home to the AgriFood Advanced Training Partnership (AATP), one of four higher level training partnerships that have been awarded funding by the BBSRC (Biotechnology and Biological Sciences Research Council, UK), to deliver skills and training to businesses in the agrifood sector until December 2016. Since its inception in January 2012, the AATP has trained over 600 UK based agrifood employees working at around 300 businesses.

Delegates have been welcomed from self-employed start-ups to internationally recognised corporations. Training is delivered by four leading, internationally recognised university and research institute partners: The University of Nottingham, Harper Adams University, Cranfield University and Rothamsted Research, as well as industry partners including Campden BRI and Cambridge University Farm.

Training is delivered in face-to-face short courses and e-training that can be done when and where is convenient for the student. Courses are split into four technical areas that have an impact across the whole food supply chain; animals, crops, food and nutrition and transferable skills.

Courses aim to explain the relevance and allow students to contextualise the latest scientific and technical developments that have an impact on their business. The AATP is managed to ensure that the latest industry issues and developments feature in courses and workshops. This is achieved by including industry representation at all levels of decision making including the Management Board each of the subject subgroups (animal, crop, food and nutrition) which reviews and approves new courses for the partnership is chaired by an industry representative. Funding bursaries are available to people working in a UK based agrifood business until the end of 2016. Full details can be found on the website www.agrifoodatp.ac.uk or email info@agrifoodatp.ac.uk for more information.

Placements and Knowledge Exchange

Undergraduate and MSc placements
Key contact: Judith Wayte

Placement students are available to help businesses with a range of projects such as research, testing, planning and analysis. Students can partner with businesses on collaborative projects, using their expertise and knowledge to provide high quality work.

Placements and projects can vary from short term projects (2-3 months) to longer placements (12 months) and are usually between the student's 2nd and 3rd year of study.

BBSRC Doctoral Training Partnership
Key contact: Jerry Roberts

The University of Nottingham, in collaboration with Rothamsted Research, is to share in a £67m investment from the BBSRC in a doctoral training programme to train future scientists in the areas of food security, bioenergy and industrial biotechnology, and core areas underpinning world class bioscience.

Businesses are able to take doctoral students on a Professional Internship (PiP) placement to assist in looking at strategic projects or technical challenges that may benefit from an external viewpoint.

To hear students talking about how their time in industry has influenced their future career plans see https://www.youtube.com/watch?v=5ESzWS9K2M
Please also see www.ncub.co.uk/blog/food-econ-placements or www.ifst.org/work-experience-blogs for examples of student placements via The University Of Nottingham.

Knowledge Transfer Partnerships
Key contact: Paul Yeomans

KTP Europe’s leading programme aims to assist businesses in maintaining a competitive edge, increasing productivity and create a more strategic innovation through greater use of shared knowledge, technology and skills that reside within the UK knowledge base. The KTP scheme has been running for almost 40 years and its longevity is due to the unprecedented level of success for all involved.

A Knowledge Transfer Partnership involves an alliance between three partners:
• The Business Partner
• Knowledge Base Partner
• One or more Associates – (recent graduate)

The University provides access to cutting edge research and development which can facilitate and utilise specialist skills of a recently qualified associate who can embed their expertise in your business.

The Associate will work on a project integral to your needs, working to enhance the long-term capability of the business, while being jointly supervised by your company and a senior academic.

“The University has worked with over 60 businesses to develop new products and business improvements. The KTP scheme is a great way for companies to work with universities to deliver bottom line benefits.” – Dan King, Head of Knowledge Transfer, Business Engagement and Innovation Services.
Appendices
Appendix A

The University of Nottingham Centres

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<th>UoN Centres mapped against R&amp;D Research themes</th>
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Appendix B

Courses of interest to people working in primary production

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<th>Course Title</th>
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<tr>
<td>Animal Nutrition MSc/PGDip</td>
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<td>Applied Genomic and Proteomic Sciences MRes</td>
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<tr>
<td>Applied bioinformatics MRes</td>
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<tr>
<td>Applied Biomolecular Technology for the Biopharmaceutical, Food and Biotechnology Industries MSc</td>
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<tr>
<td>Crop Biotechnology and Entrepreneurship MSc</td>
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<tr>
<td>Crop Improvement MSc/PGDip</td>
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<tr>
<td>Global Food Security MRes</td>
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<tr>
<td>Plant Genetic Manipulation MSc</td>
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<tr>
<td>Sustainable Bioenergy MRes</td>
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Courses of interest to people working in post-harvest

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<td>Crop Improvement MSc/PGDip</td>
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<td>Global Food Security MRes</td>
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<td>Plant Genetic Manipulation MSc</td>
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## Appendix B continued

### Courses of interest to people working in new ingredients development

<table>
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<td>Brewing Science PGCert/PGDip/MSc</td>
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<td>AgriFood PGCert/PGDip/MSc</td>
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### Courses of interest to people working in food processing and engineering

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<td>Food Production Management MSc</td>
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<td>Brewing Science PGCert/PGDip/MSc</td>
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<tr>
<td>Brewing Optimisation PGCert</td>
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<tr>
<td>Brewing and Packaging PGCert</td>
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<tr>
<td>Chemical Engineering MSc</td>
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<tr>
<td>Industrial Physical Biochemistry MRes</td>
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<td>Environmental Engineering MSc</td>
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### Courses of interest to people working in behaviour, consumer health and clinical application

<table>
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<tr>
<td>Nutritional Sciences MSc</td>
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<tr>
<td>Clinical Nutrition MSc/PGDip</td>
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<tr>
<td>Dietetics MRes</td>
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<td>Behaviour Change PGCert</td>
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</table>
Appendix C
Innovation Support for Business

The University of Nottingham provides a wide variety of services to help make your business grow and become more profitable. The University has built a strong reputation for the quality and impact of its collaborative work, with a range of services that include research and development, offering new technology for licensing and other forms of commercialisation, providing consultancy expertise to solve business issues, and delivering training to meet staff development needs.

Support for business and industry at the University of Nottingham is organised through our Business Engagement and Innovation Services (BEIS) department. The department provides a range of services for both major corporates businesses and the SME business sector, with support and advise services delivered through a number of dedicated teams:

Corporate Partnerships Team – develops and manages long-term strategic relationships with key corporate businesses in order to enhance the relevance and impact of the University’s research and training activities, derive increased industrial income and further the University’s external reputation.

Ingenuity – a support programme for Small and Medium Sized Enterprise – the Ingenuity programme’s main aim is to transfer knowledge and expertise from the University into the local and regional SMEs sector, thereby helping them innovate and grow by providing access to funding for Innovation Vouchers, graduate placements and Knowledge Transfer Partnerships (KTPs). Ingenuity provides SMEs with opportunities to attend events and workshops delivered by experts on business and innovation as well as being part of a business directory of over 1000 other businesses. It also works with and supports many SMEs from outside the East Midlands in both the UK and overseas thereby providing significant networking and supply chain brokerage opportunities.

IP Commercialisation Office – helps to commercialise technologies which have been developed through research by licensing the use of our technologies to a third party, utilising joint ventures to develop technology further and through investing in spin-out companies which frequently retain close links to the university. With our strong links to industry and investors, the IP Commercialisation Office provides invaluable market knowledge and experience, which is used by a highly professional team of Intellectual Property specialists to foster University research and develop it into marketable businesses.

Asia Business Centre – helps businesses establish links with the University’s international campuses helping them to exploit opportunities available in the rapidly expanding markets of South East Asia. By working with the Asia Business Centre, businesses can access our world leading research and development, our renowned training and education programmes and our state-of-the-art facilities. We have also championed unique and flexible skills development programmes and qualifications to meet the needs of employers globally. With campuses in China and Malaysia, Nottingham continues to enhance its growing international reputation.

If you would like to know more about how to engage with the University, please contact:

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Corporate Partnerships Senior Executive
Food & Drink Sector
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Email: amreesh.mishra@nottingham.ac.uk

Ruth Eccles
Corporate Partnerships Officer
Food & Drink Sector
Phone: 0115 74 84 778
Email: ruth.eccles@nottingham.ac.uk
For further information, please contact:

Business Engagement and Innovation Services (BEIS)
e: beis@nottingham.ac.uk
t: 0115 74 84 555

The University of Nottingham has made every effort to ensure that the information in this brochure was accurate when published. Please note, however, that the nature of the content means that it is subject to change from time to time, and you should therefore consider the information to be guiding rather than definitive.

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