**Institution:** The University of Leeds

**Unit of Assessment:** UoA6 (Agriculture, Veterinary Science and Food Science)

## 1. Unit context and structure, research and impact strategy

### 1A. Vision and Highlights.

The **School of Food Science and Nutrition** (SFSN) at the University of Leeds (UoL) has an established track record of internationally recognised research in Food and Nutritional Sciences. Our research addresses the primary drivers for public health and the food industry, through multidisciplinary research and innovation. Central to our strategy is the integration of Food Science *with* Nutrition, the aim being to elucidate the mechanisms by which foods and diets influence health outcomes as part of a sustainable food system. Strategically, SFSN is part of the Faculty of Environment (FEnv), with a global reputation for research in climate, earth sciences and environmental sustainability. Aligned to FEnv's strategy, our research also considers the environmental impact of food production and consumption.

**Our vision** is to be a world leader in food science and nutrition research that underpins food and nutritional strategies to enhance health, taking into consideration food safety, consumer acceptability, and environmental sustainability. Our research outputs influence industry practice, food policy and dietary guidelines that benefit consumers across the lifespan, at a regional, national and globally scale (Figure 1). Selected indicators of success since REF2014 include:

- Academic FTE has doubled to 29.4 through 21 new appointments to support existing strengths in food colloids and nutrition epidemiology, and created new areas of activity in bioprocessing, molecular nutrition and sustainable food systems.
- PhD awards have trebled to 83, with significant growth in industry-facing Centres for Doctoral Training (CDTs).
- Research income has increased nearly fourfold to £16.4 million. Highlights include one European Research Council Starting Grant (£1.7 million), Global Challenges Research Funding (£2.3 million) and industry funding (£2 million).
- Three-fold increase in Scopus-indexed publications to 1060 with 48% in top decile journals (CiteScore), 56% with international and 7% with corporate co-authors, 10% increase in field weighted citation index to 1.90.
- Prestigious awards: Nutrition Society Elsie Widdowson award for Excellence in Public Health Nutrition (2016, *Evans*); Nutrition Society Silver Medal (2018, *Moore*); Royal Society of Chemistry Food Junior Medal (2020, *Sarkar*); Elected Fellow of the Royal Society of Wales (2020, *Collins*).
- Achieved Silver Athena Swan Award and gender balance across academic grades through appointments and promotions.
- Research outputs has influenced industry practices, dietary and food safety guidelines internationally.
- Research has resulted in 5 patent applications and a spin-out company.

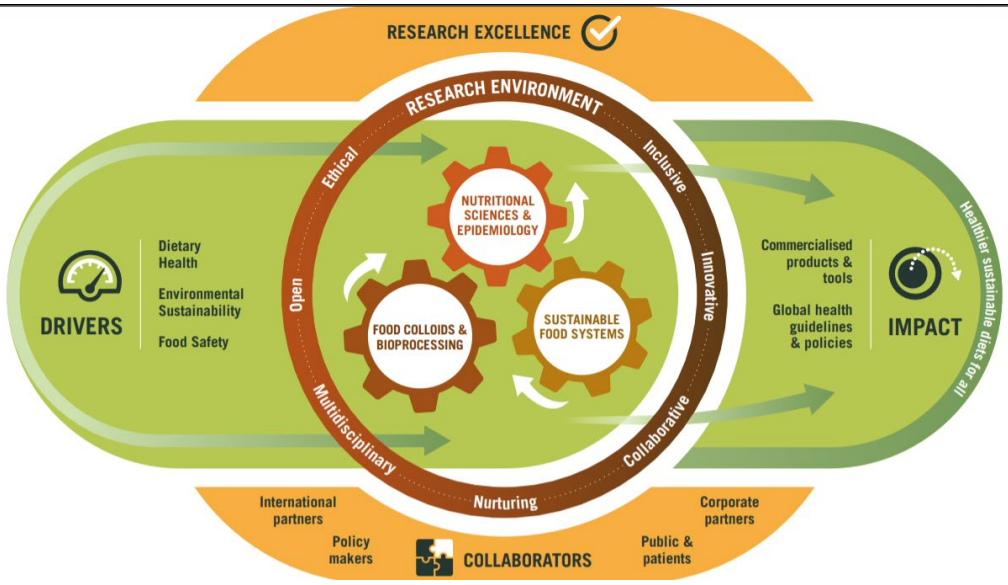


Figure 1. SFSN vision, strategic drivers and impact goals.

## 1B. Structure and context.

The R&I Committee develops the five-year rolling strategic plan considering internal and external influences (Figure 2). The Committee consists of the Director of R&I (DoRI), Research Group Leaders, International Leader, Innovation Leader, Director of Postgraduate Research Studies (DPRS), REF Leader, and an Early Career Researcher (ECR) representative. A research administrator supports the implementation of the strategic plan by overseeing open access procedures, data sharing, public and policy engagement, and equality, diversity and inclusion (EDI). The Head of School (HoS), Head of the Technical Team and School Administrator (who oversees HR and finance), are ex-officio members.

The DoRI contributes to faculty and university strategy and identifies opportunities for cross-faculty research programmes, including CDTs, Doctoral Training Partnerships (DTPs) and strategic investment in staff, facilities and equipment. Other members of the R&I Committee also contribute to Faculty and University strategy in areas within their remits. SFSN staff contribute to leadership of University, national and international initiatives (see section 4).

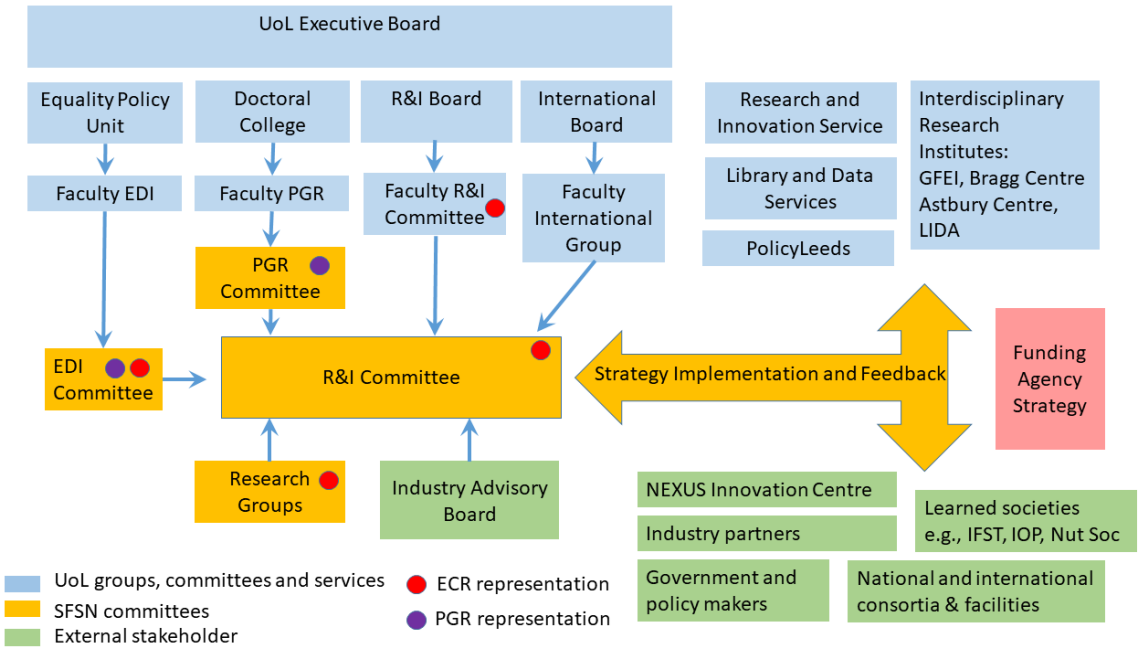


Figure 2. Pathways for R&I strategy development, implementation and feedback.

## 1C. Research and Innovation Strategy.

Research activity is primarily driven through by two Research Groups: **Food Colloids and Bioprocessing** and **Nutritional Sciences and Epidemiology.** However, new strategic appointments have allowed the creation of a third group, **Sustainable Food Systems**. There is extensive collaboration, between the groups and more widely across the University, nationally and internationally.

Over the last 10 years, our strategic aims have been implemented through the following five objectives:

***Objective 1- Increasing research capacity to create a vibrant, inclusive and sustainable academic community.***

SFSN has undergone significant strategic expansion, transforming it from a unit of research excellence primarily focused on fundamental physical and chemical aspects of food to one that now embraces major global challenges. Academic numbers have doubled during the REF period, from 14.9 to 29.4 FTE (table 1), through an ambitious recruitment programme in specific areas that has attracted international talent with multidisciplinary expertise, contributing significantly to international research outputs and scholarly activity (section 4).

Postgraduate Researcher (PGR) provision has increased from 29 to 83 awarded degrees, supported by three industry-facing CDTs and investment in scholarships, training, and facilities. High employability of these students in academia, industry and government highlights SFSN's strong contribution to increasing national and international scientific capacity.

Food Colloids and Bioprocessing:

The group has a global reputation for colloids research. It uses physico-chemical approaches at various scales to understand the behaviour of food components within their processing and biological contexts, addressing the needs of the food industry to improve the nutritional quality, food safety and environmental sustainability of processed foods. The strategy of the FCB group has been to consolidate their position as a world-leading group in food colloids research through strategic expansion in two interlinked areas of existing strength: 'Biophysics and Bioprocessing' and 'Colloidal Aspects Impacting Human Health'.

Biophysics and Bioprocessing: This area of research aligns with EPSRC's strategic priorities in Biophysics and Soft Matter Physics. Research by *Povey* on the physical properties of food lipids has led to new understanding of triglyceride polymorphisms. To provide critical mass and extend the scientific approaches to study the properties of lipids and membranes, *Rappolt* was appointed as Chair in Lipid Biophysics. This area of research was enhanced with the appointment of *Tyler* as University Academic Fellow (UAF) in Lipid Biophysics, *Smith* as Lecturer in Biochemistry with a focus on lipid biochemistry and computational biology, *Simone* as Lecturer in Food Crystal Engineering. Two further appointments *Castronovo* as Lecturer in Biochemistry and *Ponjavic* as UAF in Biophysics, have established new areas of activity in nanoscale molecular biology

Colloidal Aspects Impacting Human Health: Health is a key driver for the food industry and a priority area for funders and consumers, it continues to be a key strategic driver for SFSN, for over 10 years. Complementing expertise in fundamental food colloids (*Murray, Ettelaie*) with health aspects, *Sarkar* was appointed as Lecturer in Food Colloids. In collaboration with global food industries and researchers from a range of academic disciplines, they have undertaken research on how surface and colloidal properties affect oral processing and satiety responses. Research activity impacting health was further enhanced through appointments of *Mackie* as Chair in Colloid Chemistry and *Goycoolea* as Chair in Biopolymers with research expertise in digestion and mucosal interactions, biopolymer science and biotechnology. The modelling capability of the group was enhanced through the appointment of *Chappell* as Lecturer in Food Colloids whose research focuses on the interaction of mineral nanoparticles with the gut mucosa and other biomaterial interfaces.

Nutritional Sciences and Epidemiology:

The group addresses global health challenges related to diet and nutrition using a combination of approaches. Using evidence from epidemiological research, and more recently molecular nutrition, the group designs interventions for health outcomes and carries out research in preclinical models elucidating mechanisms at the cellular and physiological level.

The group was traditionally known for research excellence in nutrition epidemiology (*Burley*, *Cade, Evans*) and food and nutritional biochemistry (*Williamson, Bosch, Marshall, Morgan, Orfila*). Over the REF period, the group has strategically expanded nutrition epidemiology research and extended existing strengths in biochemistry with mechanistic molecular nutritional sciences.

Nutritional Epidemiology: Strategic appointments widened experimental approaches and international scope. *Ensaff* was appointed as Lecturer in Nutritional Epidemiology to enhance capability in mixed methodology interventions for improving public health nutrition in children and adolescents. *Zulyniak* was appointed as Lecturer in Obesity to enhance molecular epidemiology research, including the application of Mendelian randomisation to understand diet-related disease risk in different ethnic groups. *Gong* was appointed as Associate Professor of Food Safety and Global Health. Their research uses epidemiological and clinical trial interventions to examine how food toxins influence biochemical pathways and health outcomes.

Mechanistic Molecular Nutritional Sciences: Strategic appointments were made in this area, highlighted as a priority in the 2015 UKRI cross-council vision for Food, Nutrition and Health. *Thorne* was appointed as UAF in Diet and Epigenetics, having long-standing collaborations with research groups at St James Hospital in Leeds and applying a range of cellular and molecular biology tools to investigate how cancer biology can be modulated by dietary components. *Moore* was appointed as Associate Professor of Obesity to establish molecular nutrition as a research area at Leeds and uses genomic, proteomic and systems biology approaches to understand the role of hepatic nutrient metabolism in healthy ageing, obesity and metabolic-associated fatty liver disease. *Hopkins* was appointed as Lecturer in Nutritional Physiology to extend research to regulation of appetite and energy metabolism, both in experimental and free-living conditions, building on strong collaborative links to the Human Appetite Research Unit, School of Psychology (Blundell and Finlayson). *Campbell* was appointed as Lecturer in Metabolism and Metabolic Disease, taking a multidisciplinary approaches to understand the role of nutrition and exercise in the prevention and management of type 1 diabetes. *Guo* was appointed as Lecturer in Nano-Glycobiology, extending expertise in molecular biology to investigate adaptive immune responses mediated by carbohydrate binding receptors. *Hernandez* was appointed as Lecturer in Nutrition and Global Health. With the World Health Organization (WHO) and Food and Agriculture Organization (FAO), their research has contributed to new protein quality values for traditional and alternative proteins.

Sustainable Food Systems:

Environmental sustainability is and will continue to be a driver for societal and economic development. Our most recently developed research activity in **sustainable food systems** aims to tackle the pressing, linked issues of climate change and malnutrition across the lifespan, complementing expertise from the other two research groups. As part of this strategy, SFSN has made key appointments. *Collins* was appointed as Chair in Animal Sciences, N8 Agrifood Chair in Smart Agri-systems, and Director of the National Pig Centre (NPC). Research aims to develop systems-level forecasting tools by quantifying predictors of animal health and performance, using data from multi-platform monitoring systems and machine learning techniques. *Dunshea* was appointed as Chair in Animal Growth and Development, specializing in dietary strategies to prevent heat stress in livestock and humans. The joint appointment with the University of Melbourne is increasing international industry links. The expertise in animal science complements human nutrition expertise, and aligns with international targets for net-zero agriculture. *Morganti* was appointed as UAF in Food Transport and Logistics with expertise in sustainability and social aspects of food e-commerce and distribution, extending expertise in mixed methodologies and whole-systems research approaches.

***Objective 2- Promoting interdisciplinary working to address global issues in food and nutrition.***

Interdisciplinary research led by SFSN combines experimental with theoretical modelling approaches to propose and validate new mechanisms of how food and diets influence health. Interdisciplinary working is facilitated through themed seminars, sandpits and crucibles to generate collaborative grant ideas, and through joint supervision of PGRs. Ten research themes facilitate integration of new staff members and exemplify key areas of interdisciplinary activity. Interdisciplinary posts shared with other schools have driven interdisciplinary working (*Gong* with the School of Medicine, *Morganti* with the Institute for Transport Studies and *Ponjavic* with the School of Physics). Several projects exemplify SFSN's interdisciplinary working, including the LubSat project (*Sarkar*, ERC grant 757993) with collaborators from Physics, Dentistry, Mechanical Engineering, Electrical Engineering and Psychology. Together they developed the first biomimetic tongue using 3D-printing that will help streamline research and development for oral care, food products and therapeutic technologies (*Sarkar*). In collaboration with the Faculty of Medicine and Health, iron nanocomposites to address iron deficiency have been formulated aided by computational design principles (*Chappell*). The PigSustain project (*Collins,* BB/N020790/1) brings together biologists, vets, epidemiologists, engineers, data analysts and economists to investigate resilience of the UK pig industry to future stressors. The project has been included in an OECD report offering international guidance on interdisciplinary working as an example of best practice.

UoL research institutes, overseen by the Dean for Interdisciplinary Research (Ref5a), facilitate cross-disciplinary working. SFSN contributes to the following UoL institutes: the Bragg Centre for Materials Research (Murray and Simone on the Management Board), the Astbury Centre for Structural Molecular Biology (Guo is member, leading several interdisciplinary grants (BB/R007829/1) and the Wellcome Trust (097354/Z/11/Z); and the Global Food and Environment Institute (GFEI, *Orfila* is Associate Director).

Externally, SFSN contributes to several national and international initiatives that facilitate interdisciplinary research (section 4). SFSN academic staff contribute to the leadership of the N8 Agrifood initiative (*Collins, Mackie, Moore, Morganti, Sarkar*), a £10 million HEFCE-funded programme that evaluates the integrity and resilience of global Agri-food supply chains in the face of environmental and socioeconomic challenges. The programme has led to multi-partner and multi-sector projects (>£15 million in grant funding to UoL) and policy impacts.

***Objective 3- Enabling ethical, reproducible, open research in an inclusive environment.***

SFSN actively promotes and enables reproducibility of research, from conception to dissemination. This is facilitated through tailored training sessions and support for all researchers on reproducibility, research design, ethics in research and data management (Ref5a). Central to our participation in multi-centre studies is the harmonisation and validation of transparent protocols. Examples of success include several multi-centre dietary trials (Optifel, Pathway27, BBSRC DRINC green tea trial), multi-cohort epidemiology studies (InterLACE) and INFOGEST digestion protocol harmonisation and validation (*Mackie*, protocol cited >1600 times). All research involving human participants has ethical approval from the relevant ethics committees (University or NHS REC), and clinical trials and meta-analyses are preregistered in international databases (clinicaltrials.gov, ISRCTN, Prospero).

Data sharing is supported by UoL Open Research Team and The Leeds Institute for Data Analytics (LIDA). An example of a substantial open data set is the UK Women's Cohort data set consisting of around 20,000 dietary records linked to NHS disease and mortality data and accessible to researchers through LIDA. The UK Women's Cohort has made numerous fundamental contributions to the understanding of the impact of diet on women's health. A recent output by *Cade* on the influence of diet on age of menopause onset received worldwide attention (in the top 5% of research outputs scored by Altmetric).

SFSN provides a vibrant, supportive, nurturing and inclusive environment for researchers at all stages of their career to enhance their creativity and critical independence. Alongside the strategic expansion in academic staff numbers, SFSN has invested in new laboratory facilities and

equipment, support staff (technicians, data manager, impact and research support administrators, bespoke training and networking opportunities). We are committed to the principles of EDI, and have developed and implemented detailed action plans for gender and race equality (section 4).

***Objective 4- Building strategic international partnerships in Food Science and Nutrition research.***

SFSN has a long history of research collaboration with European universities, research institutes, industry and policy makers. Our international strategy has been to maintain our strong European links whilst expanding collaborations and strategic partnerships with China and Sub-Saharan Africa. SFSN appointed *Gong* as International Leader to implement the international aspects of the R&I strategy. SFSN's track record of international collaboration is evidenced by 40% of research income and 56% of outputs occurring with international collaborators. Our international outlook is additionally reflected in recruitment and support practices. Fifty-five percent of academic staff are classed as international, fostering scientific collaborations that address global challenges. Staff are supported to collaborate internationally through funded sabbatical and exchange programmes (*Sarkar* to ETH Zurich, *Simone* to South China Institute of Technology, *Evans* to University of Tokyo, *Ettelaie* and *Morgan* to Zhejiang Gongshang and Shanxi Universities). Since 2014, SFSN has hosted 119 visitors from 17 countries and established multiple strategic partnerships with prestigious research organisations in China and Africa.

Examples of strategic partnerships and projects with Chinese Institutions:

- The 'International University Consortium of Food Science and Nutrition', established in 2015 with founding members from SFSN, consists of researchers from leading Food Science departments including the UoL, and Universities of Guelph, Massey, Massachusetts, Kyoto University and Wageningen. The Consortium funded 4 Postdoctoral Fellows to address the role of food oral processing across the age span on health outcomes.

- The 'Food Reassurance Joint Laboratory', established in 2015 between Jiangsu University and SFSN, was supported with a £1.0 million investment to develop remote sensing technologies for food safety. Leeds joined the Jiangsu 2020 Consortium in Agricultural Technologies to broaden opportunities across the food-environment nexus with partners globally. The initiative has led to staff and student exchanges, international meetings, and 26 joint publications.

- Long-standing collaborations with the National Institute for Nutrition and Health and the Chinese Centre for Disease Control and Prevention has led to a UKRI GCRF project entitled 'Combined Food Systems Approach to Scaling-up Interventions to Address the Double Burden of Malnutrition' (*Gong*, *Ensaff*, *Moore,* BB/T008989/1).

- A Memorandum of Understanding (MoU) was signed between Zhejiang University and UoL in 2017. Collaboration led to a successful IUK/BBSRC/Newton proposal to valorise Chinese citrus waste for food and non-food applications in line with China's clean growth agenda (*Orfila, Bosch, Goycoolea,* BB/S020950/1).

Examples of strategic partnerships and projects with African Institutions:

Building on a 20-year history of collaborative research with institutions in Tanzania, Benin and Gambia, collaborative links have broadened and strengthened over the REF period, benefitting from GCRF funding. The BBSRC-GCRF AFRICAP project (*Gong, Orfila,* BB/P027784/1) will contribute to the evidence base for policy advocating climate-smart and nutrition-sensitive agricultural approaches in sub-Saharan Africa.

The University signed a MoU with the University of Pretoria in 2019. The strategic collaboration has led to a PhD training grant in Nutrition-Sensitive Agriculture (*Orfila, Ensaff,* BB/T017309/1) and the recent award of the BBSRC FSNet ARUA Centre of Excellence in Food Security. This will involve SFSN staff mentoring up to 20 African ECRs following a network+ model.

***Objective 5- Maximising impact on public health policy and industrial innovation.***

Our impact strategy aims to create and disseminate knowledge that influences industry practices, public health policies and dietary guidelines for the benefit of consumers, regulators and industry, both locally and globally. SFSN's impact activities are supported from inception to dissemination by a dedicated UoA6 Impact Support Officer, as well as UoL support from 'Policy Leeds', 'Engaged

Research' and commercialisation teams (Ref5a). Collaboratively, SFSN staff (*Moore*, *Evans*) lead nutrition policy activity as part of the N8 Agrifood Policy Hub.

Impact on public health policy and society: Research from SFSN influences policy and practice through commissioned research and expert advice (see section 4). We support co-creation of research questions through multi-stakeholder sandpits and end-user workshops, and engage policy makers and users in project design, evaluation and dissemination of outcomes.

- Policy-oriented research outputs contribute to the evidence base for dietary guidelines and safety standards worldwide. For example, research commissioned by the Department of Health by *Evans* contributed >50% of the evidence to the report by Scientific Advisory Committee on Nutrition (SACN) on 'Carbohydrates and Health', which underpinned the change in dietary guidelines for sugar and fibre intake in 2015, and the introduction of the Soft Drinks Industry Levy in 2018 (UoA6-1). Research by *Gong* in collaboration with policy stakeholders (e.g., EFSA) has led to policy development establishing safe levels of aflatoxins in foods (UoA6-2). In 2018, SFSN was designated a WHO Collaborating Centre for Nutritional Epidemiology (*Evans* is co-director), with the remit to support WHO in collecting, analysing and interpretation of dietary data in the context of nutritional epidemiology.

- Patient-oriented research involves patients and medical practitioners in research co-design. Collaborative research with the Leeds Teaching Hospitals NHS Trust is extensive and includes validation of biomarkers of nutrient status and toxin exposure in healthy and diseased individuals (*Cade,* PR-R10-0514-11004). Research involving the Breast Cancer Research Action Group (BCRAG), Breast Cancer Research UK and the NIHR's Nutrition and Cancer Collaboration Group has led to greater understanding of dietary interactions with cancer biology and therapeutics (*Thorne,* 3T57/9R17-02 and PO 1605-382). Research involving diabetes charities and patient groups (JDRF, Diabetes UK) has led dietary and lifestyle recommendations for type 1 diabetes management (*Campbell*).

- Engagement of civil society includes the design of food interventions that inform school food policies (*Evans, Ensaff,* UKPRP School Network GENUIS MR/S03756X/1). Strategic engagement with stakeholders in the Leeds City region, including council leaders, businesses and charities, has established an 'Urban Food Observatory' as a living policy lab to contribute evidence for urban strategy and policy development (Ref5a). Internationally, we engage with FANRPAN to co-create research that generates evidence for policy change, promoting sustainable development in Africa (UoA6-2).

Impact on industrial innovation: Research in SFSN addresses primary drivers for the food industry, namely health, safety and sustainability delivered through innovative research. We deliver industrial impact by engaging industry in innovative research and by translating knowledge, expertise and discoveries into innovation outputs. The innovation strategy has been to i) increase collaboration with industries, both large and small, through various funding mechanisms; ii) build a strong Intellectual Property (IP) Rights portfolio and iii) to seek IP licensing and spin out opportunities where appropriate. Industry-relevant outputs include industry co-authored publications (7% of total outputs), patents (5 filed) and the creation of a spin-out company (Dietary Assessment Ltd).

SFSN appointed *Sarkar* as Innovation Leader to implement this aspect of the R&I strategy. *Sarkar* is the N8 AgriFood Lead for innovation at UoL and is supported by the SFSN Industry Advisory Board (IAB). Membership of the IAB has increased to include representatives from 28 industries across the food system. The new Nexus Innovation Centre supports SFSN with expertise in IP protection and commercialisation of research, supports spin-out activity, and brings new commercial opportunities (REF5a). SFSN has hosted industry-networking events every two years for the last 10 years, providing opportunities for networking and co-creation.

Over the REF period, industrial interactions have increased and broadened. Over >46% of research income involves industry partners, with £2.0 million in direct industry funding, £5.2 million in industry-driven research (IUK/KTP) and a further £1.0 million through financial support for studentships. SFSN is involved in the leadership of three industry-facing EPSRC CDTs: Molecules to Product, £5.1 million, 2019-27), Soft Matter for Formulation and Industrial Innovation (£5.6

million, 2019-24) and Soft Matter and Functional Interfaces (2014-19). The CDTs include over 20 multinational member companies (e.g., GSK, Nestlé, Pepsico, Syngenta). As an example, *Povey* has led a programme of research on lipid crystallisation in collaboration with both multinationals and SMEs. Through a long-standing collaboration with the Nestlé Research Centre in York, the research has led to the design and adoption of a novel tempering unit operation that improves product quality and reduces energy utilisation in the chocolate manufacturing process (UoA6-3). Other examples are included in section 4.

In all the areas above, SFSN engages with relevant stakeholders through leadership activities including the scientific planning, hosting and chairing of associated international conferences which contain embedded policy or industry-focused discussions. Stakeholder groups include national and international learned societies (e.g., British Dietetic Association, Nutrition Society, Institute of Food Science and Technology, British Medical Association, Institute of Physics, Royal Societies), food industries, and policy makers (e.g., Food Standards Agency, Parliamentary Committees, European and Chinese Food Safety Authorities) and NGOs (e.g., WHO, World Cancer Research Fund, OECD).

**1D. Future plans.**

The R&I strategy for the next 5 years will continue to build on interdisciplinary and international collaborations to address the global challenges of sustainable food production, dietary health and food safety.

A planned Chair appointment in 'Microbiome and Energy Metabolism' would interrogate how the physical and chemical forms of food affect metabolic health through microbial interactions. SFSN has already invested £0.8 million in research laboratory space suitable for biosafety category 2 microbiology. This area would align with fundamental and applied research activities at SFSN, the NPC and clinical activities of the Gastroenterology Group in the Faculty of Medicine and Health.

A planned chair appointment in 'Artificial Intelligence in Food and Nutrition' will use large data approaches to understand the interplay between food production, consumption, health and sustainability, building on ongoing activities of GFEI, and strengthening links with LIDA and the Alan Turing Institute (REF5a). These areas will be supported with associated lectureships and dedicated facilities.

**2. People**

**2A. Values and Codes of Practice.**

SFSN's values align with the University's values of inclusivity, integrity, ethical research and international impact. We promote and implement institutional policies that support staff to work effectively (Ref5a). We regularly gather feedback from our staff and students, adopting a local approach to improve practices and culture. Over the REF period, we have increased participation of diverse staff groups and students in committees, and work closely with HR, the Leeds Doctoral College (LDC), Organisational Development and Professional Learning (ODPL) and the Research and Innovation Service (RIS), in providing training and mentoring to develop staff and students to their full potential. Over the REF period, SFSN has improved its EDI performance in terms of gender, achieving gender balance across staff grades, most notably at professorial level. We recognise the need to increase ethnic diversity and are committed to the principles of the Race Equality Charter with an action plan to improve representation of Black and Asian scientists across all areas of activity and leadership.

**2B. Staffing strategy.**

SFSN is committed to providing staff and students with an environment that provides flexible opportunities for professional, personal development, and career progression. SFSN follows the University's Code of Practice for the Management and Career Development of Staff and implements local action plans developed to meet the needs of staff and PGRs.

In 2010, SFSN set out an ambitious strategy to expand in specific areas (section 1, table 1), supported with investment in facilities, equipment, technical and administrative support, and studentships. Chair/Associate and Professor appointments have enhanced leadership capability

(*Mackie* and *Collins* are HoS, *Goycoolea* is DoRI, *Moore* leads the NSE Research Group, *Gong* is International Lead, and *Sarkar* is Innovation Lead).

Professional and career development support for staff:

Staff receive a comprehensive induction on aspects of research, student education and administrative processes. Staff are allocated to a line manager who facilitate achievable and measurable objectives for the probation period (2 years for academic staff), reviewed annually through the UoL Staff Review and Development Scheme (SRDS). Staff are supported to achieve their career aspirations through mentoring, training and access to internal (e.g., committee membership, leadership roles) and external opportunities (e.g., membership of advisory boards). A suite of training is available to all staff through ODPL (REF5a). When staff leave, they are offered an 'exit interview' to feedback on their experience in SFSN. Annual culture surveys provide information and feedback for action planning. The Reward and Recognition Exercise has rewarded several SFSN staff for significant contributions to the University. A University-wide mentoring platform is in place to connect mentors and mentees in different areas of expertise.

| | REF2014 | REF2021 | New Posts | Promotions |
|---|---|---|---|---|
| **Academic Staff** | | | | |
| Category A submitted | 14.9 (47%) | 29.4 (52%) | 20.2 (48%) | 8 (75%) |
| Professors | 5 (16%) | 8.6 (50%) | 3.2 (25%) | 2 (100%) |
| Associate Professors | 5 (60%) | 4.8 (60%) | 2 (100%) | 3 (66%) |
| Lecturers | 4.9 (66%) | 16 (50%) | 14* (50%) | 3 (66%) |
| Independent Researchers | 1 (100%) | 0 | 0 | 0 |
| **Support Staff** | | | | |
| Research Technicians | 0 | 6 (66%) | 6 (66%) | 2 (50%) |
| Research Admin Support | 0 | 2 (50%) | 2 (50%) | 1 (100%) |

Table 1. Staff profile of SFSN in FTE (percentage female) over REF census periods). * three of these appointments are tenure-track University Academic Fellows (UAFs).

Additional support for Academic Staff: New academic appointments are supported through workload remission during the first year for grant and output writing. They are also provided with start-up funds for equipment, consumables, travel and studentships. Support for new chair appointments also include funded Postdoctoral Fellows. Through annual academic meetings with the DoRI and HoS, academic staff discuss strategy, career development and promotion opportunities, while also considering workload and personal circumstances. Plans and mentoring are put in place to support the promotion application process. There have been 8 academic promotions in the REF period.

In addition to University wide support by RIS and ODLP (REF5a), grant and manuscript writing are supported through surgeries, peer review and mock interviews. Support for specific fellowships schemes is provided centrally (e.g., EU office, RIS) and complemented with local support. UAFs have a dedicated programme of training and development, organised centrally (REF5a). UoL central teams support staff with data management plans, and developing meaningful public engagement and impact activities. In 2017, SFSN implemented a new sabbatical policy to enable research activities, for example large grant applications, spin-out activities and international collaborations.

Additional support for research staff: SFSN supports the personal and professional development of postdoctoral researchers. Hence, we work to the principles of the Research Concordat (including a minimum of 10 days p.a. on professional development) to support the development of researchers at all stages of their career. SFSN actively supports the transition of researchers to academic or industry positions through their involvement in academic activities (e.g., co-supervision of PGRs, lead authorship, support for fellowship applications), membership of committees, student education and public engagement.

Postdoctoral researchers have an active 'researcher forum' where they discuss issues and share practices. In 2019, SFSN appointed an ECR champion (*Hernandez*) to develop local action plans to enhance the research environment. The ECR champion has representation at School and

Faculty R&I Committees, feeding into higher-level plans. Funding is available for their professional development, research visits, conference attendance and specialised training. The Faculty has also appointed a postdoc champion (*Ensaff*), to develop new initiatives for researcher career development, such as a postdoc network, induction activities, masterclasses and interview schemes.

**2C. Training, professional and career development support for PGRs.**

PGRs are very important to our overall strategy to develop the next generation of scientific innovation leaders. PGR students are recruited via a rigorous application process that includes a research proposal and an interview. Support for PGRs is coordinated by the LDC, which provides a central hub for information and support across the University. PGRs are additionally supported by the DPRS, who provides school-level induction and holds regular meetings with all PGRs, both as a group and in 1:1 meetings. All students have a supervisory team (min 2 members) allocated at the start of the project and regular meetings (min 10 per year) are mandatory. Furthermore, PGRs have an informal peer support buddy system.

The University's Graduate Record of Achievement and Development (GRAD) electronic system records all aspects of the PGR journey, from admission through to final examination. A detailed training plan is agreed at the start of the research period by the student and the supervising team, and reviewed at least annually. Progress against training objectives are recorded in GRAD, giving students the opportunity to reflect on their own progress. Elected PGR representatives sit on school and faculty PGR committees to influence change.

Training is a combination of generic research training offered by the LDC, supported by ODPL and the UoL Library, and individual discipline-specific training. Generic training includes sessions on research methodology, management, data management, ethics, academic writing and dissemination. The refurbishment of the Edward Boyle Library included the creation of a dedicated Research Hub and Researcher Support Service for PGRs (REF5a) offering 1:1 support on many aspects of research training (e.g., literature searching, academic writing, data management) in addition to self-help resources through an online learning platform. SFSN supports PGRs to develop academic skills for publication, dissemination and impact through training, peer and school support (e.g., writing groups, peer review). In 2018, the SFSN introduced the option of the 'thesis by publication' format (requiring 2 accepted papers and one more in draft form), and since then 23% of students have taken this opportunity.

Discipline-specific training is co-created by PGRs and their supervisors and involves participation in group meetings, SFSN and institutional seminars, attendance at national and international conferences, internal and external technical training, access to taught modules via Blackboard, and visits to other labs and/or industry facilities. In line with UoL strategy to implement blended, research-informed learning, SFSN secured funding to develop two Massive Online Learning Courses (MOOCs) aimed at PGRs from around the world (*Gong*, British Council Educational Partnership and *Orfila*, *Ensaff*, BB/T017309/1).

Industry-relevant training is a central part of CDT training, which not only provides scientific cohort-based training to create future leaders (e.g. large-scale food processing), but also transferable skills training to translate science to business (e.g. MiniMBA, innovation tools, enterprise skills).

All PGRs are encouraged to disseminate their research. SFSN PGRs organise an annual conference, and present at UoL and LDC events. Funding is provided to attend one international conference (independent of funder). PGRs contribute to output and impact activities (e.g., 11% of REF outputs, 20% of patents, delivery of public engagement activities such as Pint of Science).

The SFSN PGR population is largely international (62% international, 10 nationalities) and to support them, UoL offers dedicated language support and a popular programme of inclusive social events (e.g., Chinese New Year, Christmas and Eid celebrations). Beyond graduation, PGRs remain part of the SFSN community, connected through the alumni office and the SFSN group on LinkedIn. Many are mentored after they leave by their supervisor or research group leader.

**2D. Equality, Diversity and Inclusion.**

EDI is embedded into SFSN's culture, policies and practices, so that all staff and students are treated in a fair and equitable manner, empowering them to perform to their full potential. The UoL has clear policies and processes designed to support and protect all staff and students, including

the EDI Framework, the Policy for Dignity and Mutual Respect and the 'Partnership Agreement' (REF5a).

Using the guiding principles of institutional policies, SFSN develops local-level action plans through the EDI Committee which has representation from many groups (academic, technicians, PGRs, admin staff) and characteristics (gender, sexual orientation, ethnicity, disability and those with and without caring responsibilities). A dedicated EDI Officer chairs the Committee, with the HoS and HR lead attending ex-officio.

The committee identifies barriers and enablers to EDI practices and behaviours, and proposes local solutions for long-term improvement, feeding into faculty and university level EDI policies. The recent Athena Swan Silver Award shows the drive for continuous improvement. We recognise the need to increase representation of some ethnic groups in SFSN and became a member of the Race Equality Framework to improve mutual understanding and put measures in place to address racial inequalities.

SFSN promotes a family friendly culture. Pre- and post- parental and carers support is offered through flexible working opportunities, 'Keep in Touch' days, workload reductions, and support with PGR and project supervision. For parents, there is funding for childcare to attend training outside working hours, and a safe space for infant feeding.

The sense of collegiality in SFSN is evidenced by the high scores in the annual Partnership Survey. The majority of students and staff agree that SFSN recognises and celebrates diversity. In the 2019 Staff Culture Survey results, 92% of female and 97% male staff agreed with the statement 'I feel that my School is a great place to work'.

**Advancing female careers** has been a priority over the REF period. SFSN has been successful in achieving gender balance across academic grades, with strong representation of females in academic Committees and leadership responsibilities. In particular, the number of female professors has increased from 1 (20% of professors) to 5 (50% of professors). SFSN has worked strategically to diversify leadership positions both in terms of gender and ethnicity - Director of Student Education (*Marshall*), DoRI (*Orfila* until 2019), DPRS (*Bosch*), Innovation Lead (*Sarkar*), and International Lead (*Gong*). Female staff engage with targeted training programmes such as Springboard and Aurora (*Evans, Gong, Orfila, Sarkar*) and note improved confidence in taking the next step in their career, as well as becoming mentors to colleagues. SFSN has played an active role in ensuring that conference, meeting and committee programmes are inclusive and representative in terms of gender and race. We invite female external speakers from academia, government and industry to give keynote presentations and departmental seminars, and arrange follow-up meetings with staff and students.

**3. Income, infrastructure and facilities**

**3A. Research Income**.

During the REF period, the strategy has been to increase and diversify our portfolio of research income, resulting in an increase from £4.3 to 16.4 million (table 2). We have a balanced funding portfolio, with diverse sources of income (Figure 3A). UKRI funding is from BBSRC, EPSRC, MRC, STFC, NERC and IUK, including GCRF. EU funding includes FP7, Marie Curie, ERC fellowships and EU governments (e.g., Danish Research Council). Direct industry funding from a range of companies (e.g., AB Agri, Arla Foods, Cranswick, Christian Hansen, Danone, DSM, Kellogg's, Mars, McCain's, Nestlé). Charity funding includes many patient-based charities (e.g., Breast Cancer Research BCRAG, British Skin Foundation, Diabetes UK) and international charities (e.g., WHO, Bill, Melinda Gates Foundation, Newton). In-kind research income from successful large-scale facility awarded proposals amounted to £738k. Processes are in place to support grant writing including monthly grant surgeries by research groups, peer review of grants above £100k, mentoring, mock interviews, and sabbaticals. This is in addition to centralised support RIS and NEXUS (REF5b). Given the uncertainty of EU funding landscape, our strategy to diversify income streams and to explore other international funding will ensure sustainability.

| | REF2014 | REF2021 |
|---|---|---|
| Research Income (£/FTE) | 287,609 | 559,346 |
| Research Income (£ million) | 4.3 | 16.4 |

Table 2: Summary of research income over REF periods.

**3B. PGR funding.**

Funding for PGR research comes from a variety of sources (Figure 3B), including UKRI, industry, international funding agencies, and charities. UKRI funding has been primarily through three EPSRC CDTs: SOFI, SOFI$^2$ and M2P, through White Rose DTP BBSRC allocations and through BBSRC and EPSRC Case studentships. Industry support is through CDT and Case studentships with cash contributions in excess of £1.0 million, and fully funded scholarships.

SFSN has invested >£900k in studentships and financial support for PGRs. This included PGR studentships for newly appointed academic staff, match funding for Home and International Scholarships and financial support for PGR training.

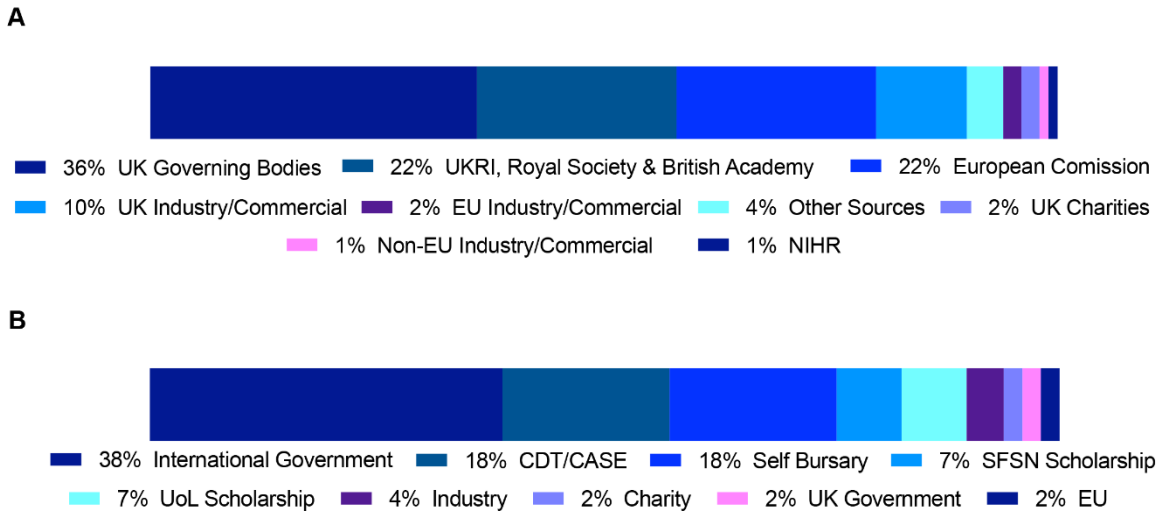


Figure 3: Percentage grant (A) and PGR (B) income by funding source.

**3C. Research infrastructure, facilities and support.**

SFSN has invested £2.2 million in research infrastructure and equipment, and £1.0 million in research support staff.

**Infrastructure.**

Investment in research infrastructure included the refurbishment of nearly all existing research facilities (£625k investment), as well as extending laboratory footfall through a £1.5 million investment in new high spec 755 m$^2$ of new laboratory space and associated office space. This includes facilities for biopolymer and food digestion research, for human appetite and exercise physiology experiments, extended cell culture facilities to handle human biopsies, with associated molecular biology laboratories, laboratories suitable for category 2 microbiology, new computer clusters for high performance computing and modelling work, and a new analytical suite for food and nutrient analysis. We have also extended computer clusters, so that each PGR has an allocated desk with a computer, from their first year until thesis completion.

**Technical and administrative support for research activities.**

Technical support for research has significantly increased, and now includes 4 full-time technicians to assist with laboratory management, training, H&S and technical assistance in the following research areas: (i) analytical chromatography instrumentation, (ii) biological research to support cell culture, microbiology, and molecular biology, (iii) colloids and physical sciences

research. In 2020, UoL became an official Partner Affiliate with the National Technician Development Centre. In addition, a database manager was appointed to support epidemiological research and general data management.

**Equipment and facilities.**

SFSN invested £900k in capital equipment, £500k in laboratory equipment, and £225k in service contracts for equipment. All equipment is available to staff and researchers across SFSN, supported through dedicated technical support. Most equipment can be booked through an online booking system and is networked with central UoL IT servers, ensuring primary data safety. All equipment is accessible to researchers across the unit, and are listed in institutional and N8 instrument databases.

**Generic equipment and facilities.**

Analytical equipment is hosted within analytical air-conditioned suites and include HPLC and LC with a range of detection systems (MS, DAD, fluorescence, ELSD, PAD, including a Waters Xevo TQ-XS LC-MS for the analysis of biological small molecules in metabolomic, nutritional, and toxicological studies (*Gong, Mackie, Marshall* BB/R013500/1), GC-MS, and asymmetric flow field-flow fractionation (AF4)/size exclusion chromatography (SEC) platform equipped with auto sampler, sample collectors and multidetector systems (DRI, MALS, DLS, UV/VIS), several high-resolution scanning spectrophotometers; atomic absorption, fluorescent spectrophotometers, FTIR, and semi-automated equipment for proximate analysis. Preparative equipment includes 2 ultra-fast centrifuges (static and swinging rotors); microwave extractors, ultrasonic homogenisers, freeze-dryers, lyophilisers, polymer separation and purification equipment (ACTA protein fractionation and system). Microbiology facilities have category 2 hoods with static and shaking incubators. Food preparation equipment include pilot scale retorts, evaporators, mixers, grinders, homogenisers, dryers.

**Specialised equipment and facilities.**

**Food Colloids and Bioprocessing** laboratories are equipped with various specialist pieces of equipment that measure the dynamic nature of colloidal assemblies, including interfacial rheometers, surface tension apparatus (static and oscillatory Wilhelmy plate and drop/bubble shape) contact angle Langmuir troughs, controlled stress rheometers, texture analysers; tribometers, quartz crystal microbalance with dissipation monitoring (QCM-D), Foamscan with bubble-forming rigs and pressure drop apparatus for foam stability measurements, ultrasound velocimeters, Acoustiscan apparatus for monitoring creaming/sedimentation; high pressure flow through food processor, Brewster angle microscopy, atomic force microscopy (AFM), ultrasound microscopy, small and wide angle X-ray scattering (SAXS & WAXS), light scattering apparatus for particle sizing (Ultrasizer ultrasound spectrometer) and electrophoretic mobility of aqueous and non-aqueous dispersions, UV/Vis spectrophotometry, differential scanning calorimetry (DSC), temperature controlled crystallisers , immersion turbidity and acoustic probes for real-time monitoring of multiphase processes, and high pressure emulsifiers.

We have developed a number of simulations including the INFOGEST static and semi-dynamic simulations of upper gastrointestinal tract digestion. These simulations include specifically designed tribology equipment that incorporates a biomimetic tongue surface with right deformability, wettability and topology to measure lubrication, tongue-food-saliva interactions and pH-stat devices and other flow devices to simulate gastrointestinal conditions. The models are combined with GC-MS, LC-MS, microscopy, cell culture, and SAXS to measure kinetics of oral and gastrointestinal release.

**Molecular Nutrition** laboratories are equipped with variety of modern molecular and cellular biology techniques to study the mechanisms by which nutrients affect cell function and metabolism at the organ, cellular and molecular levels. The molecular biology laboratories are equipped with state-of-the-art equipment and facilities for different workflows covering extraction and characterisation of small molecules, DNA/RNA and protein workflows, tissue and cell culture facilities equipped with automated cell counter and camera as well as automated device for measuring the trans-epithelial/endothelial impedance of cell monolayers under physiological conditions, cell homogenisers, quantitative polymerase chain reaction (qPCR) with high

throughput capability for >4000 reactions/day (Quant Studio 7) for analysis of mRNA, miRNA, and synthetic RNA species, multi-infrared and near infrared scanning and imaging system (Odyssey CLx), high-end sonication for chromatin and DNA shearing (Picoruptor), liquid handler for dispensing liquid with 1uL resolution, multi-mode microplate reader with advanced LVF monochromators, highly sensitive filters, and an ultra-fast UV/vis spectrometer (CLARIOstar Plus) and atmospheric chamber for modulating environmental gas composition (SPARK10M), as well as more conventional protein/nucleic acid analysis methods (ELISA, gel electrophoresis, etc).

We have recently established a purpose-built energy balance laboratory with equipment for the measurement of human body composition (dual energy X-ray absorptiometry (Lunar *iDXA*), air displacement plethysmography (BodPod) and multi-frequency bio-electrical impedance (Tanita mc-780ma) and energy expenditure (indirect calorimeter fitted with a ventilated hood system (Cosmed Quark RMR) in response to food intake and exercise (cycle ergometry using a breath-by-breath metabolic cart). This facility also includes a research kitchen and experimental cubicles that allow the measurement of appetite and food intake. There are dedicated human dietary trial facilities for blood and urine collection. Blood samples are processed for isolation and culture of lymphocytes, macrophages, and dendritic cells; blood lipid analyser (Affinion); glucose and hormone measurement. Close liaising with clinical staff at St James's and LGI allows tissue sampling including ultrasound-guided biopsy.

**Central and Collaborative Facilities at UoL.**

SFSN researchers have access to facilities and equipment throughout the University and Leeds Teaching Hospitals. Examples of facilities and equipment regularly used by SFSN include chemical characterisation facilities (mass spectrometer, NMR, fluorescence spectrometer), bio-imaging facilities including high-throughput imaging (Operetta), live cell imaging/tracking (IncuCyte), confocal, SEM, TEM and cryo-TEM), cell sorting (FACSMelody and Cytoflex, BBSRC equipment grant, T*horne* Co-I), confocal and super-resolution microscopy, dual AFM/confocal (JPK Nanowizard PicoQuant). Biological samples can also be assessed using an array of -omics techniques including core RNA/DNA sequencing (HiSeq 3000, MiSeq, ONT minion), protein mass-spectrophotometry, all with bioinformatic analytical support via LIDA and Leeds-omics. Other specialised facilities include flow mediated dilation (FMD) measurements, higher risk microbiology, gut microbiome sequencing. We also have access to a clean room and e-bean lithography, state-of-the-art AFM imaging facility for in-liquid scanning (Brucker FastScan and Nanowizard AFM), single-molecule total internal reflection microscopy and other structural biology techniques through Bragg and the Astbury Centre.

**National facilities.**

We are part of the White Rose High Performance Computer initiative, allowing access to cloud and grid computing facilities at the UoL, UoSheffield and UoYork for implementation of in-house and open access code for Monte Carlo and Brownian Dynamics simulations. Additionally, we share and have access to other equipment through the N8 equipment database.

The **Diamond-Leeds SAXS Facility** (£1.5M EPSRC strategic equipment grant, *Rappolt*, *Tyler*) is an open user and multidisciplinary SAX and WAX research facility at Harwell offering a rich scientific access point for UoL and UK stakeholders. More than 160 days of experimental beamtime per year allows the development and testing of new sample environments, a focus for training the next generation of X-ray scattering experts. This industry-led research facility helps to create a Network of Excellence with other related research labs in the UK. The Leeds headed facility is managed within the framework of the Diamond-Leeds Collaboration agreement and strengthens the research axis between the Bragg Centre and the Diamond Light Source.

The **University farm and the NPC** hosts a smart agriculture testbed and presents a £12.4M investment to support sustainable food systems research. The NPC is part of the Centre for Innovation Excellence in Livestock (CIEL), a collaboration between twelve of the UK's leading livestock research institutions and a growing network of industry partners.

**Supporting reproducible and open research.**

As outlined in section 1, SFSN has invested in infrastructure, support and training to enable open research, and in particular, sharing of data through the White Rose Data Repository, and access to secure data storage for every researcher.

**4. Collaboration and contribution to the research base, economy and society**

***Awards:*** Nutrition Society Elsie Widdowson award for Excellence in Public Health Nutrition Award (2016, *Evans*); Nutrition Society Silver Medal (2018, *Moore*); Royal Society of Chemistry *Food* Junior Medal (2020, *Sarkar*); Medtech top 10 Regional start-ups (Dietary Assessment Ltd) (2019, *Cade*); European Federation of Chemical Engineering - Excellence Award in Crystallisation (2017, *Simone*).

***External fellowships:*** Humboldt Fellow (*Bosch*); EU Marie S. Curie RISE (*Castronovo*); Italian Ministry of Health Junior Researcher (*Castronovo*); MRC Career Development Fellowship (*Chappell*); Elected Fellow of the Royal Society of Wales (*Collins*); Wellcome Trust Career Re-entry Fellowship (*Guo*); NSERC Visiting fellowship (*Hernandez*); CONACyT Postdoctoral Fellowship (*Hernandez*); Fellow of the Institute Physics (*Povey)*; ERC European Research Council Starting Grant Fellowship *(Sarkar*).

***Visiting Professorships and Scholarships:*** Visiting Professorship at the UoSouthampton (*Cade*); Visiting Scholarship Department of Archaeology, UoCambridge (*Chappell*); Visiting Scholarship UoCambridge in the Department of Applied Maths and Theoretical Physics (*Chappell*); Visiting Lecturer UoCambridge at the Institute of Metabolic Sciences (*Smith*).

***Scientific advisory board and committee memberships:*** Association for Applied Biologists (*Bosch*); Committee on Toxicology (*Cade*),; Advisory Group member for NIHR funded BRC Bristol Nutrition BRU (, *Cade*); NHS England Diabetes Prevention (*Campbell*); Agada Diabetes Research and patient education (*Campbell*); UK Society for Behavioural Medicine (*Ensaff*); Institute of Physics (IOP) liquid and complex fluids committee (*Ettelaie*); European Food Standards Agency (*EFSA) (Gong);* Evorion Biotechnologies GmbH (*Goycoolea*); Food Hydrocolloids Trust (*Goycoolea*); Board of European Chitin Society (*Goycoolea*)*;* ISEKi-FOOD Association and Accreditation Committee (*Ho*); Advisory Council to Trustees and Scientific Committees, The Nutrition Society and BAPEN (*Moore*)*;* BBSRC Post-harvest network (*Orfila*); International Standards Organisation (*Povey*); Specialist Nutrition Advisory Board Member of Apetito Ltd (*Sarkar*); FSTA Advisory Board (*Sarkar*); Steering committee member and work stream chair for the NIHR Nutrition and Cancer Collaboration (*Thorne*); *CFSA Gong);* Children Challenging Industry project, UoYork (*Evans*), Advisory board member for project on School lunch transitions during the Covid epidemic, UoDundee (*Evans*); Fellow of the Institute Physics Food Physics Committee (*Povey*; *Tyler)*.

***Scientific leadership:*** WHO Collaborating Centre in Nutrition Epidemiology (*Evans*); First Registrar of the Association for Nutrition (*Cade*); European Nutrition Leadership Programme (*Ensaff*, *Moore*); INFOGEST lead (*Mackie*); Management board of EPSRC CDT SOFI (*Murray*); Steering group of the DL-SAXS Facility; (*Rappolt*); Product Functionalisation and Performance Theme Lead and Management board member of EPSRC CDT Molecules to Product (*Sarkar*); Management board member of EPSRC CDT CP3 (*Simone*). Representative of the Soft Condensed Matter Science Group on the Diamond User Committee (*Tyler*).

***Funding or research council panel membership:*** WCRF International (*Cade*); EU Expert Evaluator, MSCA-ITN and MSCA-IF, LIF Panel (*Bosch*); Academic Advisor Panel for Commonwealth Scholarship Commission (*Bosch*, *Ensaff*); Joint EPSRC/NERC grant review panel (*Chappell*); EPSRC Peer Review College (*Chappell*, *Tyler*); BBSRC Committee E and A (*Collins*); Newton Fund for the British Council (Environment, Agriculture and Food Sciences and Biological and Medical Sciences panels, *Ensaff*); Wellcome Trust re-entry discussion panel (*Guo*); UKRI Future Leaders Fellowships programme Peer Review College (*Murray*); Diamond Light Source Panel 2 (*Rappolt*); EPSRC early career manufacturing forum member (*Simone*); ISIS neutron and muon source panel 8 (*Tyler*).

***Editorial board membership:*** Toxicology Reports (*Bosch*); Food & Function (*Goycoolea*); Food Hydrocolloids (*Goycoolea*, *Sarkar*); Food Hydrocolloids for Health (*Goycoolea*; *Sarkar*); Scientific

Reports (*Goycoolea*); Pharmaceutics (*Goycoolea*); Journal of Food Quality (*Holmes*); Food Chemistry (*Holmes*); Food Research International (*Mackie*); Current Opinion in Colloid & Interface Science (*Murray*); Advances in Biomembranes and Lipid Self-Assembly (*Rappolt*); Journal of Texture Studies (*Sarkar*), Public Health Nutrition (*Evans*).

***International scientific conference leadership:*** 17th Food Colloids Conference (2018, *Sarkar*, *Murray*); Nutrition Society Summer Conference (2018, *Bosch*, *Moore*); ''Crystal Conversations" series of webinars with the British Association of Crystal Growth and Cambridge Crystallographic Data Centre (2020, *Simone*); Nutrition Society 'Nutrition and Cancer Networking Meeting' (2019, *Thorne*); Physics in Food Manufacture Conference (2020, *Povey*).

***Contributions to public health policy:*** SFSN has provided expert advice to international policy makers including WHO, FAO, EFSA, the Chinese Food Safety Authority (CFSA), and SACN, amongst others. SFSN has provided evidence and expert advice to WHO on trans-fatty acids (*Cade*) and polyunsaturated content of foods (*Zulyniak*), nutrient standards for baby foods (*Cade*), and aflatoxin prevention strategies (*Gong*, UoA6-2). SFSN has provided evidence and expert advice to EFSA on the allergenicity of proteins (*Mackie*) and aflatoxin limits for food and feed (*Gong*). *Evans* provided evidence to SACN on the impact of dietary carbohydrates on metabolic disease, which led to Government policy change including the Sugary Drinks Industry Levy and brought about change in industry practice to reduce sugar content of foods and beverages (UoA6-1).

***Contributions to business and enterprise:***

Novel manufacturing processes: Research by *Povey* on the polymorphic crystalline behaviour of lipids has led to the design of novel, disruptive processes, including an alternative to industrial chocolate tempering (UoA6-3) and applications in non-food processes (*Povey*, patents US2019091602A1 and GB2548117A), and sensing techniques for industrial granulation processes (EPSRC grant EP/M026310/1, IUK grant 31587-233189 with P&G, and BBSRC DTP BB/N504294/1 with Nestlé). Patent WO/2019/008059/A1 has been granted to *Murray*, *Sarkar* (2019) on fabricating stable water droplets to reduce fat in food (Assignee: Nestlé). A GB Patent (application number 2007546.1) has been filed by *Sarkar* (2020) for aqueous lubricant solution to address dry mouth conditions arising from ERC AquaLub Project (Assignee: UoL). Mexican patent was filed (application number MX/a/2015/00691) by *Goycoolea* on the formulation of antibiotic-free colloidal particles with the ability to prevent the attachment of Helicobacter pylori bacteria to stomach cells (Assignee: LKPMN S.A. de C.V., Mexico).

Re-formulation of food products: The fat content of mayonnaise was lowered by exploiting protein cross-linking (*Murray*, IUK funding with Bakkavor EP/J501694/1); new emulsifiers were developed for chocolate manufacturing (*Murray*, industrial funding from Mars); molecular modelling was used to optimise gravy formulation (*Ettelaie*, *Holmes*, KTP with GoldenFry 509597). Industry funded research by *Miller* has led to reformulation of over 80% of weaning pig feeds in Europe.

Spin-out activity: Research by *Cade* developed a new online 24h dietary recording tool called myfood24 (MRC funding G1100235). This tool has strong academic underpinning with detailed feasibility and validation studies. A spin out company (Dietary Assessment Ltd), created in 2017 by *Cade* is commercialising this tool. With IUK and Venture Capital investment, the tool is used by around 50,000 research and clinical users globally.

Consultancy: Staff engage in consultancy activities for up to 12 days/year, which can be extended with the permission of the HoS.

***Contributions to research base:*** Nutritools is an open access resource, created by *Cade*, for dietary assessment research through guidance and access to validated interactive dietary assessment tools.

***Significant Academic Collaborations:*** Over the REF period, SFSN has collaborated with over 40 international academic and non-academic institutions, 56% of outputs have international co-authors (see section 1).