

WORKSHOP REPORT

**The Relationship between Food, Health and
the Environment – a European Perspective**

MILAN, ITALY, 12 AND 13 MAY 2015



**SCIENCE
EUROPE**
Life, Environmental and
Geo Sciences Committee

February 2016

'The Relationship between Food, Health and the Environment –
a European Perspective' : D/2016/13.324/2

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The Relationship between Food, Health and the Environment – a European Perspective

WORKSHOP ORGANISED BY THE SCIENCE EUROPE SCIENTIFIC COMMITTEE FOR THE LIFE, ENVIRONMENTAL AND GEO SCIENCES



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Introduction

The Science Europe Life, Environmental and Geo Sciences Scientific Committee organised a workshop on 'The Relationship between Food, Health and the Environment' in Milan on 12 and 13 May 2015. Representatives from the Science Europe Member Organisations and external experts attended, and the multi-faceted and complex relationship between food, health and the environment was explored. The challenges for each of these fields individually are numerous and varied.

A major aim of this workshop was to identify relevant links between them and to recommend common strategies for Europe to address the future challenges of food and food-related health research, from the perspective of the life sciences.

Background

Dr Bonnie Wolff-Boenisch (Science Europe) introduced some of the current issues encompassing food, health, and the environment. The 1998 'World Health Report' from the World Health Organisation (WHO) predicted that the number of individuals affected by obesity globally would more than double from 143 million in 1997 to 300 million by 2025.¹ Indeed, the latest 'Global Status Report' from the WHO on obesity has not improved on those predictions; in 2014, more than 1.9 billion adults were overweight and, of these, over 600 million were obese. This is largely because of increasingly sedentary lifestyles, with low levels of physical activity and a high caloric intake; however, obesity can be prevented through multi-sectoral population-based interventions that promote physical activity and the consumption of a healthy diet, throughout life.²

Alongside nutrition, new challenges have arisen in the context of sustainable food production; according to the Food and Agriculture Organisation of the United Nations (FAO), food production must increase by at least 60% by 2050 in order to meet the demands of the world's rapidly growing population and income.³ Climate change has increased the pressure to find new solutions for the secure production of crops and livestock and, at the same time, food waste is increasing and agricultural practices are degrading land, water, and biodiversity.⁴ In addition, animal health is gaining more attention, as markets are increasingly global and diseases can be distributed across borders with devastating consequences. Europe is contributing to the fight against these global challenges by collaborating with countries facing problems of food security and with those that need to improve their agricultural yields and to reduce food loss.

Maximising food quantity and quality, providing access to healthy food, and empowering and motivating people to choose a healthy lifestyle are massive challenges. Action is urgently needed to combat the increasing number of human diseases that arise from obesity and/or metabolic dysfunctions in both developed and developing countries. This includes increasing our understanding of the causes and consequences of these diseases, but primarily requires fundamental changes in eating and lifestyle behaviour.

Human metabolism is, in essence, the expression of the interplay of the host genome with the external environment. Recent advances in genetics and genome analysis have revealed an unexpected complexity in this interplay, and an additional layer has been added in the form of the human microbiome. New approaches for studying the complexity of the interactions between microbes, their hosts and the environment are only just starting to produce relevant results that are helping to understand this dynamic relationship.

Format and Specific Aims

This workshop consisted of a set of presentations by key experts from different research disciplines, followed by brainstorming and a discussion of the topics that arose from the presentations. Three main recommendations were identified, which are presented in the section 'Recommendations'. The documentation of these discussions and recommendations are intended to trigger stimulating cross-disciplinary discussions – a prerequisite to addressing the urgent societal challenges that cross borders and scientific disciplines.

Professor Lucia Banci (Centre of Magnetic Resonance, Florence University, Italy) introduced the purpose and objectives of the workshop, which were to:

- ▶ expand and integrate the knowledge and relationship between food, health and the environment;
- ▶ identify gaps and scientific opportunities for future research priorities and innovation in these areas; and
- ▶ identify and formulate recommendations for future policies needed to address the current societal challenges in public health as it relates to nutritious healthy diets and sustainable food production.

Workshop Presentations

Human Health and Nutrition

The first session of the workshop addressed the field of human nutrition and included presentations by **Dr Ben van Ommen** (TNO Zeist, The Netherlands) and **Professor Hannelore Daniel** (Technical University of Munich, Germany). In his presentation 'Towards a my-health driven food economy', Dr Van Ommen pointed out "that food intake has a strong influence on our body and that an unhealthy diet with an unbalanced nutrient content can lead to diseases."

A strategy of the food industry has been to increase its revenue by providing convenience products with 'added value', and products were developed that meet consumer taste preferences but contain high levels of sugar and/or fat. Increasing the amount of sugar and fat in the diet contributes to the development of metabolic diseases, and is (in part) leading to an 'obesogenic society'. Societies globally are facing a monumental increase in the number of citizens suffering from these food-related diseases; Dr Van Ommen stated that (almost) the entire US population consumes a diet that is not on par with recommendations for a healthy lifestyle. However, a promising and welcome trend in the food industry is to provide healthy foods that support the prevention of disease. However, such foods often clash with regulatory bodies and their requirements for full scientific substantiation of any health claim.

Instead of creating new food products or implementing a costly consumer-protection system, Dr Van Ommen promoted the concept of 'consumer empowerment'. The idea being to empower citizens to take an active role in the management of their own health, behaviour and food choices. A change in consumer attitude could have a considerable impact on the health status and behaviour of the population, consequently influencing the activities of health-related organisations and the food industry. Consumer empowerment is a new approach and its significance is already evident: recent studies demonstrated that in many cases, type 2 diabetes could be prevented by dieting and better self-management. Consumer empowerment is also an important topic on the agenda of the European Commission.⁵ Informed, empowered citizens are the drivers of economic change, as their choices boost innovation towards health preservation and disease prevention.⁶ Critical for this process is not only providing the right framework that allows increased consumer participation, but ultimately, really changing habits and mentality surrounding food intake and exercise. However, these new concepts will only work if food and diet are considered from a holistic point of view. Food can be very personal and the act of eating contains an emotional component; it is not simply about which foods are considered healthy or unhealthy. Food is a part of our different cultures, relationships, family life, mood and identity, and some foods are very much about pleasure.

"In order to successfully implement a system that empowers the consumer, it is important to consider the personal, emotional and psychological layer," Dr Van Ommen stated. "To change consumer behaviour, an individual and holistic approach is needed, in addition to merely addressing a larger group of stakeholders."

Modern technology grants access to, and exposes consumers to, an enormous amount of information, but the volume of it can leave consumers overwhelmed, which in turn can lead to a reluctance to make decisions. Nonetheless, developments such as the 'big data trend' and new smartphone applications could support the decision-making process of the consumer by providing 'information filtering' systems, making it easier to make healthier decisions. Thus, consumer empowerment needs a new industry of service providers, not only for food and diet incentives, but also in the area of information communication technology (ICT), (self-)diagnostics, mobile health advice and trusted third-party information providers.

In her presentation 'From Genome to Phenome – Personalized Nutrition', Professor Daniel pointed out that although humans are genetically very similar, their phenotypes vary tremendously, demonstrating the plasticity of the human body. The diet-genome interaction has a large influence on health and

disease, but our knowledge about exactly how this interaction works is still scarce. Studies performed on twins have provided valuable information on to what extent normal physiology (and also disease) is influenced by genetic or environmental factors.

In studies on obesity and other associated non-communicable diseases, trials using twins that were reared apart revealed the strong role of inheritance, suggesting that in around 65% of cases of obesity, genetic predisposition is still an important factor. After thousands of years of genetic selection, humans have evolved to process calories very efficiently. However, evolution has not been fast enough to adapt the human body to the recent developments of modern life, which now consists of totally different work and life conditions than the genome had intended.

With huge efforts in Genome-Wide Association Studies (GWAS), Professor Daniel's research team has searched the human genome for small variations that occur more frequently in individuals with a particular disease than in those without that disease. Data revealed that non-communicable diseases such as type 2 diabetes can have around 100 susceptibility genes, but that the effect of such variations is usually very small. Thus, there is no evidence that genetic testing provides added value over classical methods for diagnostics of the lifestyle-dependent diseases. It is becoming obvious that a demand exists for better and more comprehensive phenotyping of humans, so that robust genome–phenome associations can be elucidated.

Professor Daniel discussed studies in which humans were submitted to a variety of challenges within a controlled environment that revealed major changes in metabolic responses, which would not have been picked up by collecting basic anthropometric data, blood and/or urine samples. These encouraging results might lead to a better understanding of different phenotypes when the defined challenges are performed on a broader scale (metabolomics). However, uniform Standard Operating Procedures (SOPs) are vital to producing reliable and comparable results and are required for better understanding of the inputs and outputs. These should be developed within an internationally standardised effort, via a human phenotype consortium.

Research Enabling Technologies: Metabolomics

Professor Claudio Luchinat (Magnetic Resonance Centre (CERM), Florence University, Italy) informed participants in his presentation entitled 'Structuring the European Metabolomics Community to Bridge Health and Food Sciences' that metabolomics is developing into an essential technology to close the gap between genotype and phenotype, and that it has great potential to be further developed into a routine diagnostic tool. Metabolomics is the study of the metabolite composition (substances produced during metabolism) within the body. The 'metabolome' represents the collection of all metabolites in a biological cell, tissue, organ, and so on, and it provides a wealth of information about overall health status.

It is known that environmental influences, people's lifestyle choices and their nutrition are extremely dynamic. However, biological systems (that is, the body) and modern technologies are stable enough that a signature as a 'fingerprint' (of metabolites) taken from blood or urine samples can provide useful information. In order to use the information for diagnostic purposes in the future, different technologies used in metabolomics need to be intelligently combined. First, a reference database should be compiled, comprising well-characterised metabolite profiles in defined sample types. The method of choice for this detailed and in-depth characterisation is nuclear magnetic resonance technology (NMR), which is expensive and time-consuming, but very precise.

The Metabolomics Reference database (METREF) is an initiative at CERM in Italy that is collecting information about well-characterised metabolite profiles. In the future, such reference databases could be used to study and compare the 'fingerprints' or signatures that are generated by the much faster and cheaper chemical analytical methods (such as Mass Spectrometry techniques). Collectively, the

8 reference profiles in the database, and other signatures, could give valuable information about a blood sample, without the need to analyse many components in detail.

To achieve the goal of using this approach as an early diagnostic tool, a pan-European infrastructure is needed, connecting health and food research. The establishment of infrastructures for the biomedical field has been fostered by the European Commission in the framework of the European Strategy Forum on Research Infrastructures (ESFRI),⁷ and several infrastructures have been established offering services and access to knowledge, technology and instrumentation. However, these infrastructures do not currently cover some highly relevant areas of human nutrition and health, one of these being the generation of high-quality metabolomics data. A first initiative has been started with EXCEMET, the expert centre for metabolomics,⁸ which is a community effort founded in 2014 by six European research institutions, aiming to close the technological gap between genotype and phenotype.

Metabolomics and Biobanks

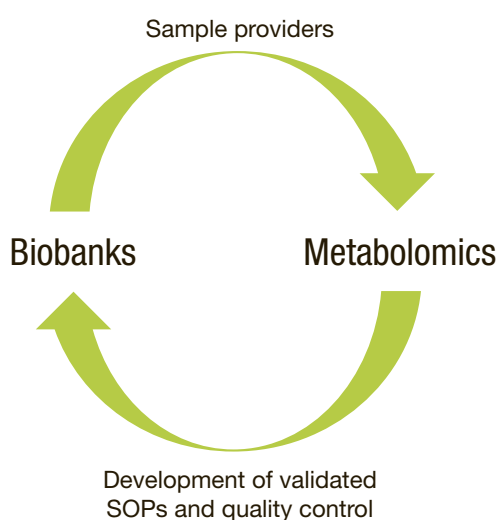


Figure 1 The existing biobanks co-ordinated by BBMRI-ERIC provide an excellent standardised source of material to generate a metabolomics data resource for Europe. [Source: Presentation of Professor Claudio Luchinat]

Professor Kurt Zatloukal (Institute of Pathology, Medical University of Graz, Austria) raised the question of whether the present understanding of biology and disease is correct, in his presentation entitled 'Metabolomics for the Advancement of Personalized Medicine and Disease Prevention'. He noted the increasing evidence that scientific studies are not reproducible due to poor data quality, or bad sample quality, study design or data interpretation, as well as an underestimation of the complexity of biological systems. There has been a paradigm shift from the previous model of 'one gene, one protein, one function, one disease, one therapy' to the modern multidimensional constitution of complex systems, wherein we need to consider molecules, cells, organs, individuals, and populations in their interactions with their environment.

A 'big data'-driven version of medicine is needed to link individual genetic make-ups to individual lifestyles, in order to achieve true 'personalised medicine' and optimal disease prevention. Metabolomics fills this gap, because the metabolome integrates all parameters, such as environmental information and microbiome interactions. Monitoring the variations of day-to-day statuses that are reflected in metabolic profiles of individuals can provide a picture of a physiological condition that is closer to reality, which can then function as an early indicator of 'disturbances'. However, this approach is not ready to transfer into practice yet. Research has started with cohort studies nonetheless, but improved standardisation and SOP frameworks are needed to create a real breakthrough in this field.

Towards a True Personalized Medicine and Personalized Disease Prevention

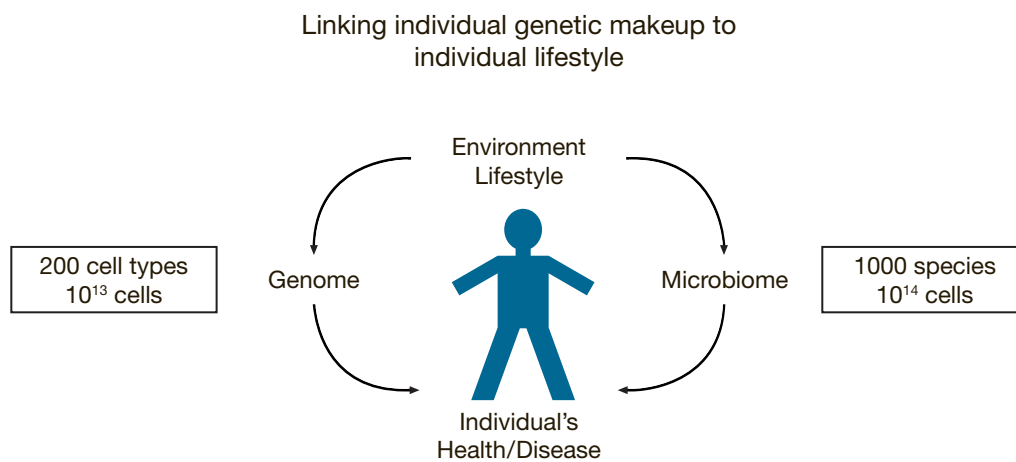


Figure 2 The human microbiome connects the environment to the human health. The microbiome has an important function in health preservation or disease development. [Source: Professor Kurt Zatloukal]

In his presentation ‘Nutrition and Stratified Approaches for Ageing Individuals’, **Dr Sebastiano Collino** (Nestlé Institute of Health Sciences, Switzerland) defined ‘healthy ageing’ as a priority challenge, as people live longer, ‘baby boomers’ retire, fertility and migration changes continue in Europe and, ultimately, the number of older members of the population grows. He indicated the need to shift focus from the ‘risk state’ towards the ‘healthy state’ of individuals. Sarcopenia (a loss of muscle mass and function) and frailty are overlapping syndromes of age-related physical decline. These deficiencies are difficult to monitor and can be nutrition-related, but (metabolic) phenotyping reveals differences between an individual’s biological and chronological age, and the optimal point for nutritional intervention is difficult to identify.

Metabolites that help to measure physiological statuses are relatively easy to measure in practice, but, in Dr Collino’s experience, they are hard to interpret. Currently, individuals over 65 are considered the ‘ageing population’, but biological and chronological age may differ between individuals; therefore, Dr Collino raised the questions of what ageing is, when it starts and whether nutrition and lifestyle can play a role in shaping the ageing process. Subgroups have been identified among the elderly, but the definition of health phenotypes within the subgroups is still extremely complicated. More research on optimising nutrition to support healthy ageing is needed.

The Human Gut Microbiome

Intense research efforts have revealed that the human gut microbiome (of internal microbes) plays a major role in human metabolism; therefore, it is an important variable to take into account when considering the management of obesity, inflammation and human health.⁹ It can be viewed as an integrator of all elements of human metabolism, and connects strongly with the environment. Expectations are currently very high that the microbiome could be the key for the cure and prevention of many diseases. Research into the interaction between food patterns, gut microbiota and associated risks of cardio-metabolic diseases are already being conducted at European level, for example in the FP7 ‘MetaCardis’ project.¹⁰

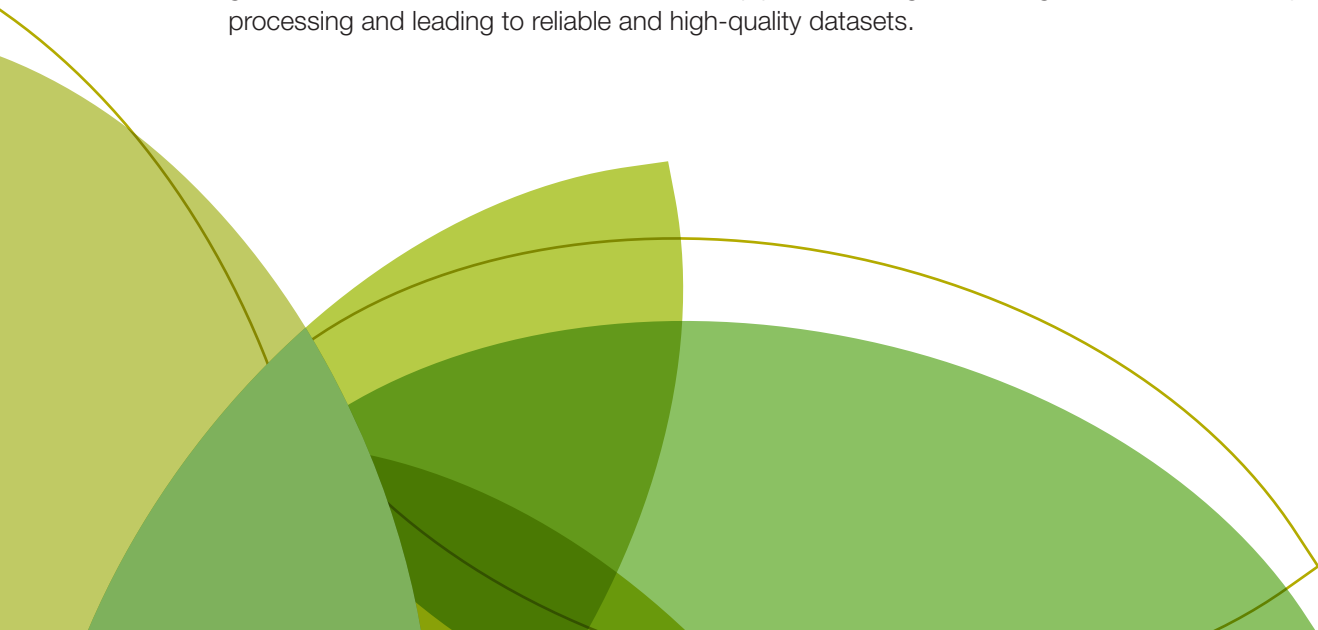
Professor Dusko Ehrlich (National Institute for Agricultural Research, France) focused his presentation on the ‘Human Gut Microbiome in Health and Disease’. He said that “chronic diseases impact healthcare systems worldwide” and that “the increase in the number of citizens with chronic diseases, especially in

developing countries, is alarming.” The major role that the microbiome – also known as the ‘neglected organ’ – plays in health and disease, and especially chronic disease, has been known, but is only being addressed properly recently. Studies have revealed that individuals with gut microbiomes lacking diversity are less healthy, and that dietary interventions that increase the diversity of the gut microbiome, may reduce the risk of illness.

Studying the interplay between the gut microbiome and the human body is difficult and requires quantitative metagenomics analysis. The complexity of this research is increased by adding the interactions of the ‘transient’ bacteria that are taken in with food, and by the open question of how certain bacteria can ‘colonise’ while others cannot. For a better understanding of the gut microbiome, a catalogue of genes generated by metagenomics analysis on the gut bacteria is a first step. Currently, the catalogue contains ten million genes, and the number is constantly increasing. This gene catalogue is being clustered into ‘MetaGenomic Units’, where the composition of the clustered microbiome can be studied. It is already known that a few species of the human gut microbiome are always present and stable, and that about 100–200 species are variable among individuals. If information about the helpful bacteria abundance and genes present in a sample or body are known (i.e. the ones driving towards a healthy phenotype), *in silico* models could be used to predict the effect of interventions on physiology. A fundamental understanding of the gut microbiome and its complex interactions within the human body could steer healthcare systems from curative to preventive medicine.¹¹

Professor Karine Clement (Institute of Cardiometabolism and Nutrition, France) studies the effects of ‘Obesity and Microbiome’ in an applied way. Based on the knowledge that the diversity of the microbiome could influence the development of cardiovascular diseases, obesity and other metabolic disorders, she studied the effect of food and diet upon it. In dietary intervention studies, investigating whether an increase in fibre and protein intake could lead to increased microbiomal diversity, the intervention was found not to lead to an ideal gene count in the gut of some subjects. When studying a specific gut microbe (*Akkermansia muciniphila*), its beneficial role was only observed when it was combined with an already diverse gut ecosystem and with other bacterial groups, showing that an effect depends on multiple players.^{12,13} In addition to having an influence on metabolic diseases, the microbiome is also known to influence immune functions, both in the intestine and at systemic levels in humans. According to Professor Clement, tissue crosstalk needs to be included in future microbiome-interaction studies. This emerging research field requires experts with specialised training to tackle the challenges and remaining questions surrounding human–microbiome interactions.

The current challenge in microbiome studies is the adoption of standards and SOPs for the production of high-quality and comparable datasets, alongside analytical pipelines. A broad-scale research approach is an important milestone, before translation of concepts into clinical practice can be made. The following areas are crucial for large-scale standardised microbiome analysis: sample preparation and handling; data production; models to test mechanisms, hypotheses and read-out; data organisation and processing; and the bio-informatics pipeline and readouts. The participants agreed that a main goal for the field is to establish an automated pipeline starting with data generation, followed by data processing and leading to reliable and high-quality datasets.



In his presentation entitled 'From Myth to Mitochondrion: the Molecular Basis of the Health-Promoting Effects of some Foods', **Professor Gianfranco Peluso** (IBBR/CNR, Italy) discussed the example of olive oil. Polyphenols have been frequently indicated as the major component responsible for the beneficial dietary effect that olive oil has on human health. As antioxidants they are believed to have a disease-preventing effect, and current evidence suggests that it is the interplay between the microbiota and polyphenols that creates this beneficial effect. He emphasised that more studies are needed to focus on mapping out the interactions between diet and microbiota and their effect on human health.

Dr Yvette Luiking (Nutricia Research, The Netherlands) addressed the problem of malnutrition and the negative health consequences associated with it in her presentation entitled 'Innovations in Medical Nutrition to Support Health in Elderly and Disease'. Nutricia has been studying the influence of dietary precursors on the symptoms of patients with Alzheimer's disease, including frailty. They examined two groups of participants, and in both groups dietary intervention had a positive effect with improved memory and physical performance. As a consequence of this and other work, an integrated approach in innovative healthcare has started; this is leading away from the current focus on patient care and disease treatment only, to an increased realisation for patients of 'quality of life' through prevention, participation and empowerment. To achieve this, it is crucial to understand the progress of disease in combination with the effect of nutrients and nutrition on disease and, later, quality of life. "The effects are much better if one starts optimising nutrition at an early stage in a disease, when the effect of the intervention can be much greater. Building on that, the next step will be to develop strategies for how the emergence of new symptoms can be avoided or prevented."

Professor Cathie Martin (John Innes Centre, United Kingdom) further contributed the perspective of the field of plant sciences towards the discussion. Her presentation, entitled 'How can Plant Science Contribute to Human Health?' emphasised the dramatic situation the world faces at the moment: by 2020, chronic disease is expected to form 60% of the global burden of disease and its mortality is expected to rise to 73% of all deaths. Alongside smoking, an unhealthy diet and physical inactivity are critical socio-behavioural risk factors for death by chronic disease (the so-called 'non-communicable diseases'). Comparative studies in the US show a high association of limited access to healthy food, high numbers of obesity and chronic diseases, and a very low average rate of daily fruit and vegetable consumption across the population. The popular '5 a day' campaign does not seem to be efficient enough.

Professor Martin described research whereby specific plant bioactive compounds were tested in various food models. It was demonstrated that anthocyanin-rich fruits and vegetables were helpful in cases of cardiovascular disease; the dose-response curve in the experiments clearly demonstrated that the highest amount of anthocyanin within the study caused a 50% reduction of aortic-dilation risk. Therefore, natural sources of anthocyanin, like blood orange or purple tomatoes, could and should be part of a healthy diet to help reduce the risk of death by chronic disease. Professor Martin summed up the potential contributions of plant science to human health as follows: "It can lead to the identification of dietary bioactives through use of model foods, an assessment of the relative benefits of dietary bioactives against a range of chronic diseases through preclinical studies, and the development of new food crops enriched in dietary bioactives through both conventional breeding and biotechnology."

In her presentation entitled 'TrEATement of Brain – Feeding our living in the 21st century', **Professor Marina Melone** (University of Naples, Italy) focused on the brain and the influence nutrition has on its functioning. Throughout one's lifespan, the human brain is constantly changing: unused connections get pruned, while oft-used connections are strengthened. According to Professor Melone, "studies show that both the environment and nutrition can influence the brain and its functioning."

Studies were reviewed whereby a correlation was found between access to food, brain size and the development of cognitive skills. There is also a known additive effect of diet and exercise on synaptic plasticity and cognition. The Mediterranean diet, which is thought to be healthier than other diets, contains mostly plant-derived elements and a low percentage of saturated fat, dairy products and meat. The 'Western' diet instead contains higher amounts of fat, sugars and dietary 'advanced glycation end' products (present in meat, for example), which are known to increase the risk of Alzheimer's disease. Diet also has an influence on epigenetics (i.e. changes in gene expression levels without changes in the gene code itself) and many dietary ingredients with epigenetic remodelling properties are already known. The influence of diet on epigenetics needs to be further studied in a more systematic approach, including investigations into how the epigenetic changes can be reverted and/or modulated.

Discussion

The relationship between food, health and the environment raises more questions than it would be possible to discuss comprehensively during one workshop. However, the discussions led to some important conclusions. Researchers are now able to study the interaction and dependencies of human health and the environment in more detail, due to increasing amounts of data recording, processing and improved biological technologies. We have begun to improve our understanding of the complexity of living systems via systemic approaches. For almost two decades, systems biology and systems medicine research have increased understanding of human health and disease and are starting to clarify how food and nutrition impact health. The influence of interactions with the external environment on, health, as well as the internal microbiome, adds layers of complexity that are now increasingly and necessarily being included in studies.

Two enabling research domains were identified during the workshop as being essential to fill current knowledge gaps in human health and disease, and to specifically elucidate the relationship between genotype and phenotype:

- ▶ Technological advances over the past decade allow study designs to further investigate the interplay between the human body and its microbiome – an important 'organ' – in more depth. Research on the metabolome can be considered the 'missing link' now needed in order to study the relationship between genotype and phenotype. Intensive efforts are needed to develop, improve and upscale the analytical methods for metabolomics studies, to gain a fundamental understanding about the status of metabolism. Metabolomics as a method is expected to be used in the future as a sensitive diagnostic tool to monitor health status, or the progress of a disease, or a therapy. The method can also be used to improve individualised prevention strategies, and detect the timing of transition from a healthy body state into one of ill-health.
- ▶ The establishment of a complementary, pan-European research infrastructure, embedded in the already existing national and European biomedical research infrastructures for human food, nutrition and health, will provide the critical mass to enable the throughput that is needed to generate a fully functional research pipeline on the matter. It would provide coherence in research methods and strategies and generate high-quality research data under standardised conditions. The aim is to build information resources on all aspects of nutrition and health research, and to generate quantitative and predictive models to gain a better understanding of the complexity of nutritional physiology. Special emphasis needs to be given to establish structures for consistent and standardised metabolomics and metagenomics research.

Almost identical recommendations were published in the 'Milano Milestone' in May 2015, a document summarising expert analysis of potential needs for food and health research infrastructures in Europe in the frame of the FP7 project 'EuroDISH'.¹⁴ A new strategic working group aims to now bring 'Health

and Food' onto the ESFRI roadmap. Tremendous value could be added if this planned infrastructure for food, nutrition and health were to be tightly linked to already-existing biomedical infrastructures; complementation of research infrastructures with specific food- and nutrition-related elements or modules would provide significant added value to the entire landscape. Research infrastructures have an essential role in advancing science because they are vanguards and multipliers that can disseminate and implement quality control and maintenance systems, SOPs, standards and best practice examples, which are vital to producing high-quality data and knowledge resources. An excellent example of this is the Biobanking and Biomolecular Resources Research Infrastructure (BBMRI-ERIC), Fig. 1.¹⁵

Regarding future research on the human phenotype (such as the further work on the microbiome and the metabolome), mapping the existing standards, as well aligning and creating new standardisation initiatives, is clearly needed, from both the research community and standardisation bodies (such as ISO (International Organization for Standardization) and CEN (European Committee for Standardization)/ CENELEC (European Committee for Electrotechnical Standardization)). Such an inventory of existing standards and SOPs will help to avoid duplication of efforts and the creation of conflicting systems in these new and emerging research fields. Doing this will foster a new generation of reproducible and re-usable datasets and studies.



Figure 3 BioMedBridges connects 12 Biomedical Research Infrastructures in Europe. Two emerging new BMS RIs, ISBE and MIRRI, are associated partners in BioMedBridges. [Source: www.biomedbridges.eu]

During the discussion, environmental aspects (including, for example, sustainable food production and food waste) were emphasised as a highly relevant dimension that still needs to be addressed in order to complete the triangle of food, health, and environmental research. **Professor Carlo Calfapietra** (National Research Council, Italy) pointed out that sustainable food production will increase in importance as a research field in the near future, not solely because of climate change, but also due to increasing demand and the need to ensure access to healthy food for all citizens. Environmental aspects need to be included at different levels of this research. Sound frameworks for a life-cycle assessment for innovative solutions, including indicators for environmental sustainability for example, are increasingly important and need to be included in research approaches on a routine level. Multiscale and dynamic modelling tools, amongst others, can be used to demonstrate the sustainability of existing food chains and their potential influence on the environment.

Research concepts encompassing all aspects of the triangle of food, health and the environment, require intensive interaction between research disciplines and an increase in multidisciplinary approaches and research consortia. To overcome traditional barriers and connect the science fields across existing silos, concepts for multidisciplinary training and education of a new generation of experts are a fundamental prerequisite for addressing existing challenges and developing innovative solutions.

The concept of consumer empowerment was discussed intensively throughout the workshop. Similar to the ‘user-driven’ technology innovation that has occurred with smartphones, music and laptops, for example, ‘consumer-driven’ food and health innovation is the way forward. To establish such a concept and shape a profitable health economy, fundamental changes need to be induced within society. Big Data could help to transform at a societal level by increasing citizen and patient involvement in the management and processing of their own health data in so-called ‘Health Data Co-operatives’, and by restoring public trust in science. The design of multidisciplinary research questions within the triangle of food, health and environment, and adding the perspective and input of the social sciences and humanities, could lead to the design of important research questions, such as: how to address the psychology of the consumer, how to encourage citizens to make appropriate, healthy food choices, and how to collaborate with the food industry and various other stakeholder groups involved. The Joint Programming Initiative (JPI) ‘Healthy Diet for a Healthy Life’ (HDHL), is one initiative currently tackling such multidisciplinary topics within Europe.¹⁶ The International Life Sciences Institute (ILSI) is another organisation through which scientists from public and private (food industry) sectors work together, pre-competitively, to strive for scientific consensus on matters of public health, related to food and health.

Professor Ruedi Aebersold (ETH Zurich and University of Zurich, Switzerland) raised the question of whether “healthy and, in the future, personalised food is the key to maintaining and/or restoring health across the population.” He said that “a prerequisite would be the development of reliable models that predict health trajectories of individuals based on sound scientific information of a nutrient–health relationship.” A support system that triggers individual lifestyle changes could potentially come from open science methods, such as smartphone applications that provide information on food composition and intake, to accelerate changes in consumer behaviour.

A realisation of revolutionary changes in eating behaviour and lifestyle in European societies will only be successful if, in parallel, the concept of consumer empowerment is implemented and enforced. The empowerment of the individual and the opportunity for participation in decision-making processes would help to advise citizens and policy makers on how best to maintain or restore health, how to secure access to both sufficient and healthy food and how to develop a sustainable and environmentally-friendly system of food production. Integrating policy makers and regulatory bodies in the current debate is a cornerstone, not only for developing the right policies and framework conditions, but also for promoting breakthroughs and innovation that will improve the quality of life of citizens.

Recommendations

A central aim of this workshop was to identify and formulate recommendations for future policies and strategies needed to address the current societal challenges in public health, as related to healthy diet. As a result of their discussions, the participants formulated a number of recommendations aimed at specific stakeholders, centred on three key topics identified, as follows:

Creation of Adequate Infrastructure to Close Knowledge Gaps in Human Health and Nutrition

Recommendations for Funding Organisations to Enable Research in Emerging Fields

- ▶ Strengthen research on human metabolome and food-response phenotypes, in a co-ordinated and highly standardised framework, to identify and better clarify genome–phenotype relationships.
- ▶ Strengthen standardised research on the human microbiome, on a broad scale in comparable studies, for the elucidation of: diet and microbiota, and their interaction with the human body; its role in health and disease; and, as a connector of the environment and human metabolism.
- ▶ Establish validated biomarkers to frame healthy, pre-disease or disease statuses.
- ▶ Member States should collaborate on the building, sharing and use of infrastructures and knowledge resources, in order to enable alignment and standardisation.

Recommendations for the Research Community

- ▶ Agree upon and develop standards and SOPs to ensure high-quality analysis and accurate scientific comparability of data. Data should first be collected across different studies as a mapping exercise, in order to define a catalogue of minimal requirements to allow for the generation of high-quality, reproducible and re-usable datasets and studies.
- ▶ Utilise standardised tools to address links between food, health and environment and generate a knowledge base to improve the health and well-being of human populations.
- ▶ Engage with multidisciplinary scientific communities and strengthen the application of multiple fundamental technologies (including metabolomics), data resources and information sources, building on currently ongoing basic infrastructural efforts towards nutrition and health research.

Laying the Foundations for Stronger Links in Research between Food, Health and the Environment

Recommendations for Funding Organisations to Enable Research in Emerging Fields

- ▶ Develop an overarching framework for innovative solutions within food and health research, and add within this indicators for environmental sustainability (environmental impact of products); these indicators need to be routinely included in food and health research approaches. For example,

new products, services or processes based on dynamic-modelling approaches, should take into account the entire chain from research to production, and include environmental, consumer and societal impact aspects (to link existing but fragmented research in food and health).

Recommendations for the Research Community

- ▶ Develop concepts for sustainably linking the research fields of food, health and the environment that will aid the joint creation of innovative solutions; for example, design of multidisciplinary research questions within the triangle of food, health and environment and embedding the perspective of social sciences and humanities.
- ▶ Create new multidisciplinary educational approaches in order to train a new type of expert: one needed to create innovative solutions for current societal challenges (with expertise spanning across traditional disciplines).

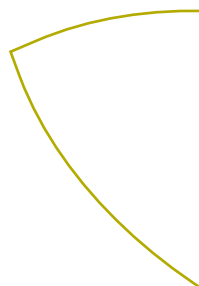
Laying the Foundations for Consumer Empowerment

Recommendations for Policy Makers

- ▶ Drive adaptation and further evolution of the regulatory framework in order to support development and implementation of innovative health solutions, including products, services and processes.
- ▶ Help the food chain and retailers to make profits by keeping citizens healthy and to enlarge the scope of their products, from food products to health services; and, establish an economic reward system for change.
- ▶ Change consumer education about food intake towards establishing 'nutrient–health relationships' and knowledge about maintaining a healthy 'energy balance' and building an environment that facilitates this change.
- ▶ In the context of a growing economic impact due to the increase of diet-related diseases, policy makers should continue to seek accurate and up-to-date scientific knowledge in order to direct food advice and lead consumers towards a healthier lifestyle.

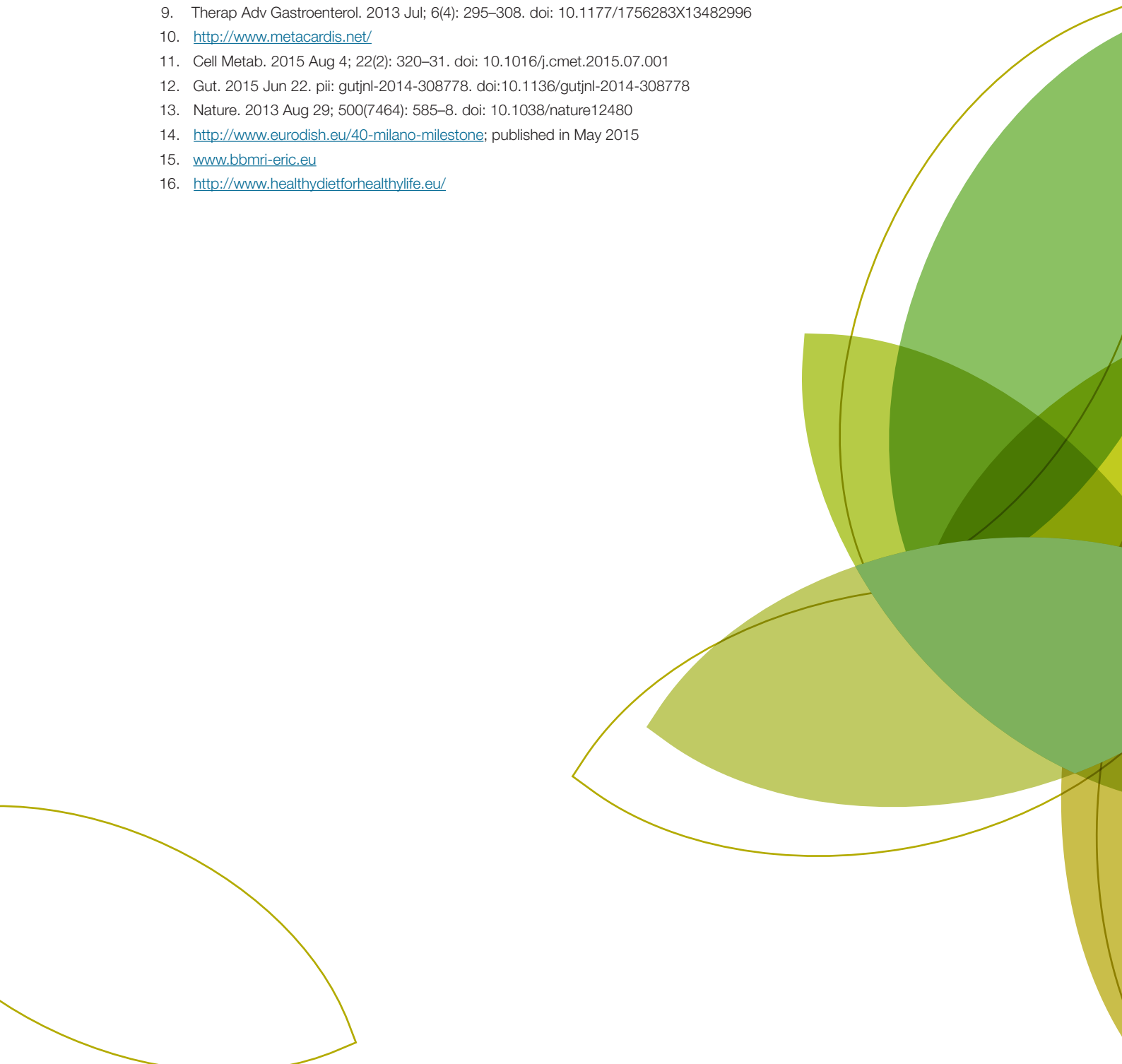
Recommendation for the Regulators

- ▶ Establish a framework that guarantees ethics and privacy for patients in health research.
- ▶ Support and shape the establishment of data co-operatives (including crowd-sourcing data) across Europe to induce changes on a societal level by consumer empowerment.
- ▶ Increase citizen and patient involvement in the management and processing of their own health data and restore public trust in science (such as via health data co-operatives).



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12 and 13 May 2015 // Hotel Sheraton Diana Majestic, Milan

Tuesday 12 May

09.00

Welcome from Science Europe

Dr Bonnie Wolff-Boenisch, Head of Research Affairs, Science Europe

Welcome from the Science Europe Scientific Committee

Dr Bonnie Wolff-Boenisch on behalf of **Professor Dirk Inzé**, Scientific Director of the VIB (Vlaams Instituut voor Biotechnologie), Department of Plant Systems Biology, Belgium

Aims and Expected Outputs

Professor Lucia Banci, Centre of Magnetic Resonance, University of Florence, Italy

Towards a My-health-driven Food Economy

Dr Ben van Ommen, TNO Zeist, The Netherlands

From Genome to Phenome – Personalized Nutrition

Professor Hannelore Daniel, Chair of Nutrition Physiology, Technical University of Munich, Germany

Structuring the European Metabolomics Community to Bridge Health and Food Sciences

Professor Claudio Luchinat, Centre of Magnetic Resonance, University of Florence, Italy

10.15

Questions

11.15

From Myth to Mitochondrion: the Molecular Basis of Health-promoting Effects of some Foods

Professor Gianfranco Peluso, Research Director, IBBR/CNR, Naples, Italy

Metabolomics for the Advancement of Personalized Medicine and Disease Prevention

Professor Kurt Zatloukal, Institute of Pathology, Medical University of Graz, Austria

Nutrition and Stratified Approaches for Ageing Individuals

Dr Sebastiano Collino, Nutrition and Metabolic Unit, Nestlé Institute of Health Sciences, Lausanne, Switzerland

12.00

Questions

13.00

Innovations in Medical Nutrition to Support Health in Elderly and Disease

Dr Yvette Luiking, Research Manager, Nutricia Research, Danone, The Netherlands

Human Gut Microbiome in Health and Disease

Professor Dusko Ehrlich, Research Director in Microbiology and Food Chain Division, National Institute for Agricultural Research, France

Obesity and Microbiome

Professor Karine Clement, Institute of Cardiometabolism and Nutrition, Paris, France

How can Plant Science Contribute to Human Health?

Professor Cathie Martin, John Innes Centre, Norwich, United Kingdom

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TrEATement of Brain – Feeding our Living in the 21st Century

Professor Marina Melone, University of Naples, Italy

14.15

Questions

14.45

Discussion: Which Areas can Yield Main Opportunities for Innovation and Breakthrough Research?

Moderator

Professor Dusko Ehrlich

15.15

Discussion: How can Europe Establish an Integrated Research into the Relationship between Food, Health and the Environment?

Moderator

Professor Ruedi Aebersold, ETH Zurich and the University of Zurich, Switzerland

16.15

Discussion: What Research Infrastructures are Needed to Establish Integrated Research in These Areas?

Moderator

Professor Lucia Banci

16.45

Discussion: Which Policies are Needed to Fulfil This Goal?

Moderator

Professor Carlo Calfapietra, Researcher at the Institute of Agro-Environmental and Forest Biology, National Research Council, Porano, Italy

17.15

Final Remarks

The Organising Committee

Wednesday 13 May

10.00

Conclusions

Moderator

Professor Ruedi Aebersold

11.00

Discussion: Content of the Workshop Report

Dr Bonnie Wolff-Boenisch

13.00

Visit to the Expo 2015

Science Europe is a non-profit organisation based in Brussels representing major Research Funding and Research Performing Organisations across Europe.

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