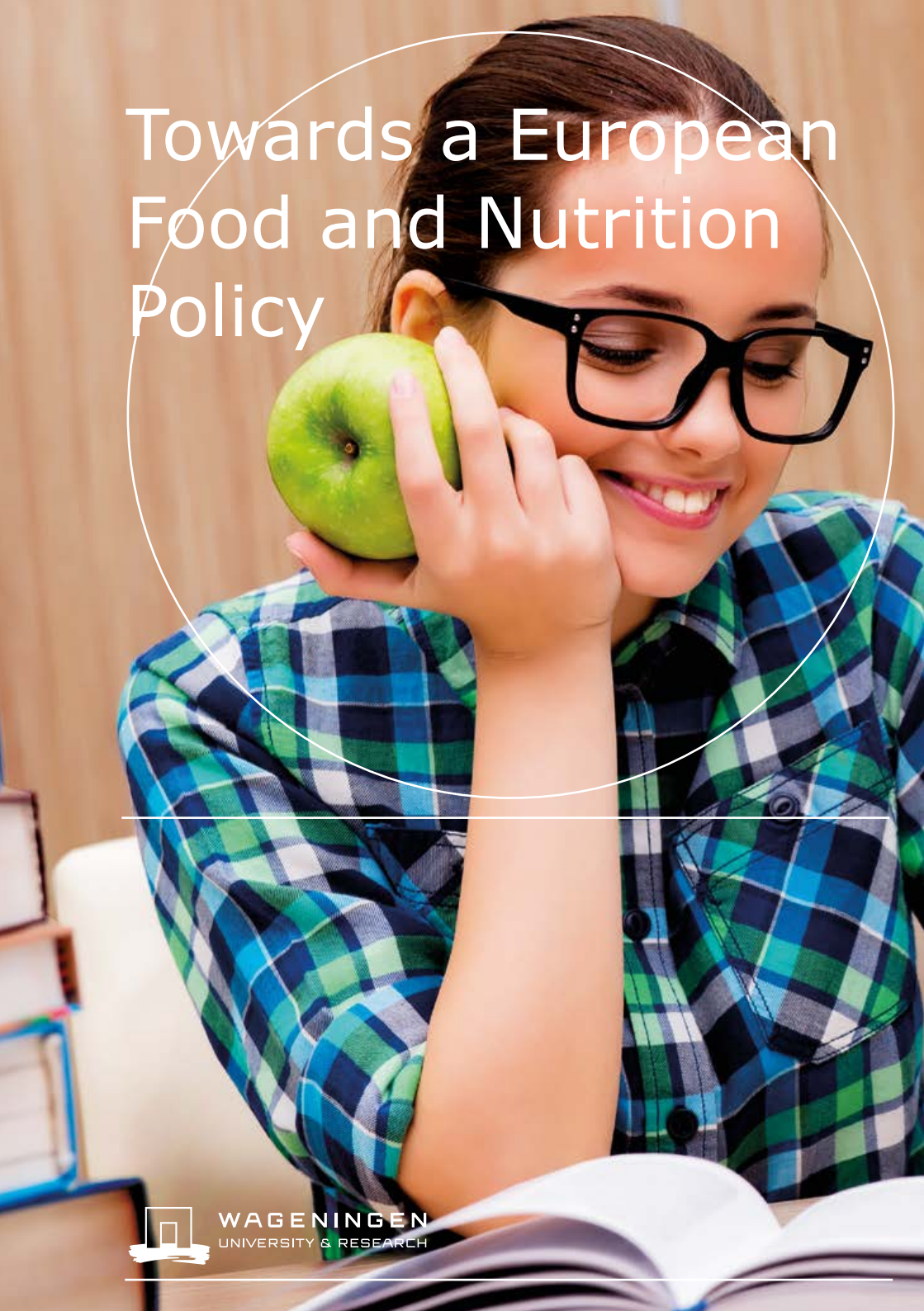
Towards a European Food and Nutrition Policy



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Towards a European Food and Nutrition Policy

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Preface

Food is pivotal to our existence, connecting us with nature and with each other. Food is essential for our growth, livelihood and health. It defines who we are and is part of our identity. No wonder almost everyone has opinions on our diets, with lots of emerging hypes and intense discussions. Most of the time we make food choices unconsciously, without thinking. But sometimes this routine is disrupted by a news item about food safety or the impact that food production has on the environment, on overweight and disease, on climate change and food scarcity. Food is an important predictor of chronic disease, with our food choices, lifestyle and living environment greatly affecting our health and quality of life. Our confidence in food also relates to trust in farmers, the food industry, supermarkets and the government. Food is about who we are in relation to our own health and the health of our friends & family. It is highly dependent on those who supply it, whether from nearby sources or the other side of the world.

Wageningen University & Research conducts research into food systems that provide diets to people in their daily life, in both Western and non-Western contexts, as part of the global community or as individuals. Wageningen University & Research is one of the few universities in the world to carry out research on food, nutrition, lifestyle and health while also studying animal and plant production systems, food technology and the economy. The challenges are great, and so are the stakes. How do we feed nine billion people in 2050? Is there enough food for everybody? How will the quality be like? Is it distributed equally? Does it provide optimal quality of life until old age? Do we exploit the earth too much? How do we safeguard the welfare of coming generations? Wageningen University & Research scientists from many disciplines work together on such questions, aiming to find new technologies and new solutions via fundamental and applied research, with public and private partners, in fields ranging from the life sciences to practical applications on a national and global level.

Food and nutrition scientists are at the intersection of social involvement and scientific independence, and answer to public and private stakeholders as well as consumers. The social challenges are too large to ignore. We work on understanding the nature of the relationship to food and the way people deal with their living environment in a globally diverse and connected world. We look for and find realistic solutions that are healthy, sustainable and acceptable for the citizens.

This must result in a match between the societal challenges and the opportunities found in nature and culture. Confidence and insight into an integrated view on food and nutrition is an essential guide in this context and this document aims to show the overarching lines of such a vision.

We would like to thank the many colleagues from Wageningen University & Research who have contributed to the discussions underlying this paper. We hope it will help to foster an enhanced appreciation of debates on food, nutrition and a European health policy, with close connections to underpinning research and practical applications.

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Need for change

Healthy lifestyles and sustainable diets require changes from consumers as well as the food system at large, including governments. Before we dive into the question of how innovation could support a change toward better diets, let us first examine current policies and practices. How far have governments, industries and consumers come on the way to effectively addressing the major challenges?

Global challenges

Public health and the agri-food system are facing several major challenges. The world population is expected to reach nine billion by 2050, urbanisation is changing the food supply and living environment, and people will live longer and develop more chronic diseases due to their unbalanced dietary patterns and obesity. Climate change will affect food production by shifting it towards the poles (further north in the northern hemisphere), resulting in major global effects on food security and socio-economic development. The food system is under pressure: is it fit for the future?

While improving health and sustainability partly go hand in hand in north-western Europe, reduction of food waste and slight replacement of animal-based foods by plant-based ones is not sufficient. Larger changes are required with a wide range of implications. It is no longer enough to simply equate the production of energy and nutrients for the average global citizen with food security and nutrition, or to draw easy parallels between environmental sustainability and global greenhouse gas emissions & use of land. Moreover, the functionality of the food system goes beyond its economic productivity for farmers, SMEs, food industries and retail: it also includes the lifestyle and physical, social & mental well-being of citizens.

The quality of diets must be balanced at the level of individual people in their communities, the environmental effects of food production must be balanced at the farm level, and economic processes must enable a livelihood for all those involved in the food chain. It is no longer sufficient to balance the inputs and outputs of the food system at a global macro level: facing the challenges has implications for policies at the level of states and individual consumers. The EU, its member states, public & private parties and individual citizens all have an intrinsic, though multifaceted, interest in food and health. During its evolution,

Homo sapiens has domesticated plants and animals and built communities and cities, arts and sciences. This development is now reaching its evolutionary and planetary boundaries, however. A new relationship between the urban and rural environment, between culture and agriculture, is needed.

Food system

People choose their diets within the constraints of their food environment, which is shaped by regional and global food systems. Our food systems, which have numerous functions, are a product of planetary boundaries, progress in life sciences, social mechanisms and dietary patterns. Multiple interacting food chains transform the geographical distribution of food and feed production to a social distribution of diet patterns, health and well-being. The food system produces, processes and transports foodstuffs and makes them available to citizens via shops, outlets and restaurants. This directly defines dietary quality, nutritional health and food safety, affecting people's physical, social and mental health and contributing to their livelihoods, participation in society and economic well-being. Food systems should ensure food and nutrition security, and need to operate within the boundaries of social, ecologic and economic sustainability. In doing so they fulfil many partially interrelated and sometimes competing functions. They need to be ecologically and economically sustainable, contribute to a minimum level of food and nutrition security, and support nutritional health in a socially inclusive way.

These multiple functions of the food system and their interrelationships have been shaped by history, starting on a small scale and growing to global interdependencies. Food system outcomes differ by level (local, global) and actor (consumer, public, private). As natural and economic resources are limited, trade-offs are inevitable and synergies need to be exploited. There are numerous societal challenges with respect to diets and consumption patterns: productivity, profit and competitiveness; local and global environmental boundaries; and fair and just social conditions for citizens and food system actors. They are made more pressing by limited resources, incomplete knowledge and diverging priorities of the food system actors. Consumers, food chain actors and producers are driven by different incentives. Consumers act on variables like knowledge, price, habits, attitudes and social & subjective norms, while the food chain and producers are confronted with a regulatory environment that influences food prices, farm gate prices, contract opportunities, natural and economic resource availability, available technology, and local environmental farm characteristics. At a higher level of abstraction, economic drivers, population dynamics, technological change, agricultural & trade policies, environmental issues, and culture & lifestyle indirectly affect the more direct drivers.

The societal challenges apparently require that different sectors of society, as a well as public and private parties, align their strategies towards providing foods that make a healthy, sustainable and socially acceptable diet the most affordable and easy choice. For instance, pulses can replace meat as a protein source for people with vegetarian or vegan lifestyles, but they are not very popular among a majority of consumers. Replacement of animal proteins by plant proteins would, however, do much to create a more sustainable world. To facilitate the protein transition, technologies are being developed that convert plant proteins to products with meat-like sensory characteristics. Although pulses may eventually become more important in people's diets, the transition can only be facilitated if private food chain actors and public policymakers agree on common objectives and create incentives to improve production systems and resource use efficiency for the major food groups in the diet. In this respect, a big challenge is to arrive at business models that combine economic competitiveness, ecologic sustainability and consumer acceptance.

Emerging global policies

The challenges of a healthy, sustainable and fair food system are concerns at the global, European, national and regional levels. Policies at these different levels ultimately affect the health and well-being of individual citizens and society as a whole.

The UN has adopted the Sustainable Development Goals (SDGs, 2015), a set of 17 goals which aim to end poverty, protect the planet, ensure prosperity for all and provide a better world where no one is left behind. These goals have been endorsed by more or less all 193 UN member states. They address social, ecological and economic issues, with major ones being 'no poverty', 'zero hunger' and 'good health and well-being'. In line with the WHO Global Nutrition Targets 2025, the Global Nutrition Report acknowledges that malnutrition and poor diets are the number one driver of the global burden of disease and that better nutrition is central to the SDGs. It therefore calls for action and a focus on stunted growth in children, food waste, obesity, anaemia in women of reproductive age, and issues related to breastfeeding, birth weight and diabetes. Economic losses caused by poor diets and nutrition contribute substantially to GDP losses, which indicates that there are potential economic gains once tangible and effective strategies are in place.

In the field of ecology, a total of 175 states have signed the Paris Climate Agreement (2015), which is presently in the process of ratification. This may become a driving force for adapting the food system (since the latter is responsible for a large proportion of greenhouse gas emissions), while simultaneously contributing to a wider set of health-related SDGs. The Food and Climate Research Network (FCRN, FAO) noted that dietary guidelines are formulated in high-income rather than low-income countries, and that they rarely incorporate sustainability issues. The Food and Agriculture Organization (FAO) focuses on nutrition-sensitive food and agriculture policies. The Global Panel on Agriculture and Food Systems for Nutrition aims to help policymakers make their food systems more supportive of high quality diets. It underscores that actions have to go beyond agriculture to encompass trade, the environment and health, harnessing the power of the private sector and empowering consumers to demand better diets. How would a sustainable food system look? According to FAO (2010), sustainable and healthy diets protect and respect biodiversity and ecosystems, and are culturally acceptable, accessible, economically fair & affordable, and nutritionally adequate, safe & healthy, while optimising natural and human resources.

The EU policy context

The Directorate General for Health and Food Safety (SANTE) of the European Commission looks at sustainability and public & consumer health separately from food systems or food chains. Its Public Health component (including health determinants) is separate from Safety and from Consumer Health (CHAFEA). Nutritional health policy concentrates on reducing the burden of obesity and diet-related diseases through diet and physical activity. To facilitate control and provide advice on food safety issues, the European Union established the European Food Safety Authority (EFSA), which takes the perspective of the food chain. EFSA's Panel on Nutrition, Dietetics and Allergies (NDA) advises on recommended intake values for macro and micronutrients, and is involved in attempts to harmonise pan-European food and nutrition surveillance. EFSA, however, does not address dietary guidelines, which are the product of health and socio-economic mechanisms at the member state level. Policies related to agricultural production, food safety and nutrient requirements are therefore organised at the EU level, whereas concrete public health measures are embedded into the socio-economic and health context at the member state level.

The EU Environmental Policy formulated its mission in its Action Programme for 2020: "In 2050, we live well, within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society." Ratification of the Paris climate agreement by member states could provide the basis to develop mitigation strategies at EU and member state levels that would address global trade, food production at the EU level, processing and distribution by food companies and retail, and the dietary patterns of EU citizens.

When it comes to research, building blocks for strategies have been formulated by the Food2030 High Level Conference. This prioritises nutrition for sustainable and healthy diets, climate-smart and environmentally sustainable food systems, circularity and resource efficiency of food systems, and the innovation and empowerment of communities. These can be intersected with ongoing trends in agriculture and marine resources, food production and processing, digitalisation and consumer food practices, and effects on health and well-being, to arrive at concrete actions. To facilitate the underpinning research, the current

fragmentation in research needs to be overcome by transdisciplinary and intersectoral collaboration. With respect to the integration of knowledge and data, the European Strategic Forum on Research Infrastructures (ESFRI) has expressed the need for a European health and food research infrastructure, which would foster breakthrough research via interdisciplinary collaboration along the food chain. This would facilitate interdisciplinary research by standardising data on agricultural and food products, as well as data on food composition and food intake related to health, socio-economic factors and consumer interests. The data, tools and services provided by such an infrastructure would support the development of sustainable food chains and products, engagement of consumers in healthy lifestyles, and coherency of socio-economic and intersectoral policies in the EU and its member states.

Role of member states

In most European countries, food and health strategies are largely separate and independent from economic, environmental and international agendas. However, in some member states there have been developments towards integration. Some take matters of sustainability into account in their food-based dietary guidelines while a number of cities have introduced a food policy and encourage healthier and more sustainable lifestyles via the social and built environment. Private companies have multinational networks but focus on specific food chains within the limits of profitable business. Both companies and governments are aware of the SDGs and act within the context of their markets and global economic developments. Effective policies, however, need to transcend individual stakeholder interests and develop coherent overarching incentives that serve common societal interests in a sustainable and healthy food system as a public good.

The EU Joint Research Centre (JRC) Foresight study 'Tomorrow's healthy society – research priorities for foods and diets' has identified integrated policymaking as being essential to healthier eating, both by strengthening the scientific evidence base and via the development and evaluation of policies. It advocates in-depth life science research on foods, nutrients and health, focusing on complexities & emerging risks and the realisation of individualised diets, including underlying data needs, feasibility and impacts. Finally, the report looks at shaping and coping mechanisms related to the food system expected to emerge in 2050, with a focus on the social role of food and the supporting technologies required to achieve societal aims, and a sustainable food system producing safe, affordable and healthy dietary components.

The report points to the importance of a societal dialogue to support the future food system, with research providing the evidence necessary for informed decision-making.

Within member states, the realisation of cross-cutting policies is often frustrated by short-term sectoral priorities and the prioritisation of direct tangible measures at the expense of less tangible and uncertain, but in the long run possibly more effective results. For instance, in the Netherlands the Scientific Council for Government Policy (WRR, 2015) report 'Towards a Food Policy' pointed to the emerging societal and ecological challenges and identified the need for an integrated food policy. The Ministry of Economic Affairs responded jointly with other ministries with a Food Agenda, pointing out which activities the government already undertakes, and formulating the ambition that the country would become a global frontrunner in sustainable and healthy food production. However it is unclear to what extent politicians consider it legitimate to influence consumer behaviour, given the ethical issues about influencing people's choices. In the meantime, the National Institute of Public Health and the Environment (RIVM) followed-up on its earlier report 'Our Food, our Health' and extended the scope from health and safety to sustainability of diet. Another example from the Netherlands is a recent law on environmental planning which – based on an amendment by community health services – now obliges all government levels to take health into account in environmental planning, which involves issues such as the food environment, green zones, physical activity, zoonoses and pollution with particulate matter. The intimate relationship between health, food and the environment appears to be taking root in the policy domain, and should eventually lead to new practices.

In the field of research, EU member states align their national research agendas via the Joint Programming Initiatives, which are bottom-up coalitions of member states rather than centrally organised EU initiatives. For instance, the strategic research agenda of JPI-HDHL focuses on determinants of diet and physical activity, diet and food production, and diet-related chronic diseases. In its 2016-18 implementation plan, JPI-HDHL prioritises the development of scientific and evidence-based recommendations for policy; research leadership in the area of food, diet, nutrition and health by competitive research; and the development and strengthening of partnerships to tackle grand societal challenges. The JPI-HDHL – possibly together with the JPIs on agriculture (JPI-FACCE) and healthy and productive seas and oceans (JPI-Oceans) – may therefore support scientific research and innovations aimed at a healthier and more sustainable European food system.

Drivers of innovation

The previous chapter sketched in five points a need for change in the (global) food system and the activities that governments undertake to push the food system in a desirable direction. We now move to the question of what science and innovation can contribute. For this purpose we first look to some of the major technological developments and changes in society that shape the food system of the future. Five trends will be briefly addressed: digitalisation, personalisation, globalisation, integration and co-creation.

Digitalisation

Research often aims to find root causes and looks for ever more detail. In the case of nutrition, this includes molecular processes in the human body, social interactions between people and transport of foods along food chains; it also includes detailed information from satellites on weather forecasting, crop growth by square metre, etc. Enabled by ICT, the digitalisation of the food system generates a flood of big data, which requires new ways to select, integrate and extract relevant information and knowledge, ultimately supporting consumers and food system actors to make the best decisions. In the domain of nutrition and health, this trend includes diets, foods & nutrients, and metabolic & biochemical processes in the body, right down to metabolomics, transcriptomics, genomics, etc.; eventually sensors and wearable tools could be connected to a miniaturised lab-on-a-chip that monitors habitual and irregular fluxes of nutrients and metabolites at the individual level. The question of what encompasses a healthy diet has become a big data challenge encompassing an infinite number of food constituents, biochemical pathways and their biological interaction with over 20,000 genes and even more genetic variants. Emerging laboratory technologies coupled with information technology and the emergence of systems biology will help us understand life and health at the level of the cell factory, tissues, organs and the body as a whole.

Digitalisation of the food environment – where people shop, what they buy, where they eat, and what this does to their physiology, physical and mental fitness – is recognisable in all aspects of food consumption. The trends in ICT apply to methods and technologies to assess dietary habits and consumer behaviour and the role of wearable tools and sensors is increasing. Objective assessments by these methods can complement and enrich questionnaires and

be used to monitor things like product choice, points of purchase, eating and drinking occasions and social behaviours. This opens up new opportunities to link biological and behavioural phenomena to dietary intake, food composition tables, sustainability indicators, price, etc. Such observational data can be further tested and evaluated using experimental approaches like brain imaging to understand preferences in terms of satiation, taste and sensory & physical rewards of foods & meals. As a result, dietary behaviours can be understood in much greater detail. Moreover, these more objective assessment methodologies allow to be standardised and become comparable across countries.

Personalisation

Currently, most dietary advice is provided via mass communication and food labelling. Personalisation refers to the trend of assessing diets and providing advice directly to individuals, rather than groups. This is relevant not only to nutrition surveillance and policy, but also to research. The engagement and involvement of consumers is at the heart of the strategy of the European Technology Platform.

Based on physiological studies of patients and other observational & intervention studies, EFSA has defined requirements for the distribution of nutrient intake within populations. These requirements are used to evaluate the nutritional adequacy of diets against a set of constraints based on physiological needs or aiming to improve population health and reduce the risk of disease. The requirements are used to evaluate nutrient adequacy based on population subgroups in Europe (e.g., EFSA) and in many countries worldwide. Combined with data on dietary habits and epidemiological trends, the requirements form the basis for dietary guidelines at the national level. Current dietary survey methods, however, are labour-intensive and struggle to capture dietary habits and behaviours in an efficient and standardised way, especially at an individual level. The abovementioned ICT trends can help enhance standardisation, the efficiency of data collection and the comparability of food habits within and between countries. This will contribute to assessing the status quo, evaluating current policies and developing more effective public health strategies for specific risk groups, while simultaneously accounting for ecologic and economic sustainability.

In addition, advancing digitalisation is expected to promote personalised assessments, enabling a better characterisation of dietary habits and its determinants than current food frequency questionnaires and behavioural

research. Although most people are usually labelled as healthy, many have abnormal clinical values for risk factors such as blood lipids, blood pressure and glucose curves. In current practice, clinicians prescribe dietary regimes to patients with moderate problems, which is tailored to individuals by dieticians, and drugs are used when such measures fail to reduce symptoms or risk. However, changing diets and lifestyles is notoriously difficult, and personalised feedback can be an important incentive for the adoption and maintaining of new behaviours. This can be based on things like shopping lists, meal preparation and eating out or at home, all matching actual circumstances with individual relevance. Moreover, digitalisation of diet and lifestyle data can be combined with physiological characteristics and biomedical risk factors of consumers, and result in personalised nutrition and lifestyle advice, possibly even including relevant genetic information. This is in line with current trends towards personalised medicine and a move from the curative to the preventive domain. Such trends are already visible in e-health, sports and the Quantified Self, and can extend from treatment of and recovery from illness to interactive learning of new food skills and the adoption of healthy habits within the social and built food environment.

Globalisation

At first sight, a trend towards globalisation seems to be at variance with digitalisation, big data and personalisation. And the current political climate (Brexit, for instance, and US views on international trade agreements) seems to suggest that the globalisation is becoming less important. But that would be too easy a conclusion. When it comes to food, all people are physically, socially and economically connected via a worldwide food system. Moreover, the societal challenges of the food system are not limited by national borders. Global warming and climate change pose new questions on planetary boundaries, the resilience of the food system and irrelevance of borders with respect to climate change. Industrial contamination of rivers and blooming algae because of eutrophication and greenhouse gas emissions are clear examples. Moreover, as climate change is transnational, so are its implications. Agricultural production will eventually shift away from the equator and to the north, with economic consequences, more migration, increased social instability and geopolitical implications.

Globalisation has contributed to the efficiency of food chains. The fixed costs of research, innovation and marketing can be paid for by a higher volume of production, leading to lower food prices. Together with free trade this leads to production in the places that are best suited to it. In integrated global chains, information can be exchanged by means other than labels, such as contracts. However, a global food system has its own dynamics and is hard to govern when it comes to public issues.

Globalisation in the food system at its current level already has major implications for health. The global burden of non-communicable diseases (NCDs, e.g. obesity, diabetes, CVD, malignancies), infectious diseases (e.g. malaria, measles) and the 'double burden of disease' (combination of over and undernutrition) in both high income and low & middle income countries call for optimising the intake of nutrient-dense plant foods relative to animal-sourced foods. As mentioned before, solutions to the diet–environment–health trilemma should seek healthier diets that produce low GHG emissions and are tailored to local ecological boundaries regarding energy, water, soil quality, etc. The social, economic and health dimension of the food system are closely related on the global scale, just as they are at the national and personal level.

Globalisation also refers to sharing information via internet, including the Internet of Things. These developments affect relationships between people and the world in a fundamentally different way than public media used to do. It is as if we see the adverse and beneficial effects of food systems on people, animals and nature all over the world not from a large distance but from everyday experience. The flip side is that information is selected, either intentionally or not, and that raises questions regarding the quality and curation of information, ownership of data and privacy of citizens, as well as the ethics of selecting and applying information. Freedom to exchange data and information does not guarantee quality. Trustworthy data, unbiased information and knowledge are not self-evident and are valuable goods. Their quality and the privacy of citizens must be protected with ethical measures.

Integration

One consequence of the abovementioned three trends that drive innovation (digitalisation, personalisation and globalisation) needs special attention: innovation leads to the integration of decisions across classical boundaries. To reap the benefits of digitalisation, different data from different areas has to be combined. The example of food consumption data and health data on a personal

level and their consequences for personalised nutrition is a good one. Tracking and tracing of foods with regards to nutrient content, sustainability indicators and sensory & cost aspects is an example from the food chain. The One Health approach, in which the collaboration between doctors and veterinarians is stimulated to improve surveillance of zoonoses and learn from each other's approach, is another. And there is an option to breed new varieties for specific health purposes (like 'golden rice'). The transitions in water, energy and food have become strongly intertwined (in the so-called food nexus) in food production.

The integration leads to multiple objectives in decision making, which has consequences on how we organise the decision-making process. Our dietary choices and the food system fulfil a number of functions in the biological, social, ecological and economic domain. There are constraints on what constitutes an adequate diet, what is preferable for consumers, what is socio-economically acceptable and what is ecologically sustainable. The present food system has developed over centuries, but is not future-proof due to the growth and ageing of the world population, together with socio-economic developments, climate change and limited resources. The question is: How can all these aspects be integrated within realistic alternatives? What wise decisions on incentives and measures can transform the food system to boost its competing and interacting functionalities in an effective and efficient way? Which diets are sustainable, healthy, affordable, reliable and preferable to consumers, not only in high income countries, but also in low and middle income ones? What foods must be produced, processed, distributed and consumed so as to stay within the boundaries? How can feed and food supply be optimised to better support the quantity and quality of consumer diets?

An integrated policy requires decisions to be taken at the proper level of governance. Taking decisions at the European level may address major directions for agricultural and public health policies, but will likely lack the level of detail needed for changing food choices by consumers or innovating product developments by food companies. For other topics, optimisation at national or regional subscales may lead to innovation pathways in agriculture and food technology that are ineffective or suboptimal for the food system as a whole and lead to loss of efficiency and resources. So which decisions need to be taken at the EU or national level and for what decisions does the regional or even the individual level suffice to achieve policy goals? Current public and private players in the food system are and will remain the first to take these questions on board in a more integrative way. But it is also likely that new players will enter the decision space of the food system, from app developers and technology firms to insurance companies and non-governmental organisations. Moreover, it is likely that the division of tasks between the public sector, commercial sector and civil society will be redrawn in this process of change.

An important aspect for decision making related to the future organisation of the food chain is how easily data will travel between organisations to make such integrated decisions. The more this is possible in a world of big data, the better current players will be able to move the food system forward. In the world of food, nutrition and health this includes the integration of data from surveillance, disease etiology and public health interventions, together with laboratory experiments to evaluate causality of associations. Public health and consumer policies build on the integrated knowledge and information that emerges from such data.

Citizen science

Although consumers can be seen as part of the food system, we see their role as a separate driving force for innovation. Digitalisation empowers individuals. Personalisation makes them unique subjects to whom the food industry and health system tailor their products and services. Data on food, nutrition and health should preferably be integrated at the individual level. It is therefore attractive to include individuals as a driving force in innovation and science, as is the case in citizen science. From a research perspective, one of the reasons why this is attractive is the fact that data has to come from citizens. Research is not necessarily built exclusively on the efforts of research organisations, but can include reliable and objective data obtained directly from European citizens. Sampling, selection and data quality remain important scientific challenges, but unlocking the potential of consumer behaviour data falls within the scope of current technological developments.

Consumers must also be involved as data on food and health is often very privacy sensitive and big data requires big trust from the primary data provider. Consent mechanisms are needed to exchange data between citizens and scientists. A second argument that supports the involvement of consumers is that new technologies, like in breeding (e.g. CRISPR-CAS), which could help solve some of the sustainability problems, are not uncontroversial. There is need for a societal debate here. A third reason is that it is ultimately consumers who decide what to eat and where. Food practice is complicated, and changing behaviour far from easy. This requires innovation processes that involve

consumers from the beginning. For some of the research questions, individual-level data may not be strictly required, and characterising diets and health at the level of the 'habitat' of citizens may suffice. For instance, when the food environment and food system are of concern, it might suffice that data is defined on a relatively refined grid (e.g. using GIS) which links city districts, shops & supermarkets and socio-economic, demographic & health characteristics on a small-scale ecological rather than individual level. Nevertheless, to obtain this data from citizens and to engage them in subsequent community interventions, it is absolutely necessary to have trust in research, food chain actors and policy makers.

Co-creation involves multiple actors along the food chain, in the public and the private domain, with consumers, food and public health at the centre. It builds on the diversity of stakeholder interests as a resource for innovation, and requires that key objectives of the food system transition are agreed upon. It could help to organise decision making at the effective level of governance. Although co-creation might be an option for innovating in the food system, it can also be seen as a mission impossible.

The current practices of consumers, public and private actors are scattered, since all actors have separate objectives, expertise and limitations, and mitigation strategies therefore need to be fine-tuned to a point of departure that is specific to each of the stakeholders involved. At which hotspots in the food chain can agriculture, food technology, and dietary habits contribute to the transition towards a sustainable food system? What is needed to create a space for innovation? There are no magic bullets in diet and health nor in ecological sustainability. But there may be game-changers in agriculture, food technology, urban planning, ICT, etc.

In summary, there is an enormous amount of information waiting to be unlocked from citizens and significant innovation power is available in the food sector. At the same time, there is a major need for effective policies in the health and environmental sector. Governance, knowledge and technology actors need to co-create effective and feasible ways to serve the needs of consumers as well as public & private actors. Before we identify these ways forward for innovation and policies, let us first look at some of the misunderstandings that need to be addressed in the communication with citizens and policy makers.

Five misunderstandings

Numerous misunderstandings on food and health pop up in the communication between policy makers, citizens and the scientific community. They are equally common in contacts with relatives at the kitchen table, when we interact with people on our way to work, and in newspapers and other media. In this chapter we mention five that are relevant to food and nutrition as key end products of the food system at large. These discussions reflect the pains and gains of citizens, and challenges for researchers, policymakers and societal actors. We mention five propositions as a starting point for discussion.

Misunderstanding 1:
health disparities are a fact of life and cannot be changed

There are large differences in diet and health within families, between communities and around the world. We often tend to look at such differences as if though they were constant and not modifiable.

At first sight, health disparities do seem rather fixed. Some diseases run in families and people from disadvantaged socio-economic groups are less healthy and do not live as long as their wealthier peers. For example, in around 2010 upper class men in the UK could expect to live 20 years after the age of 65 on average, whereas this number was just 16.4 years for working class men. The corresponding numbers for women were 23 years and 19 years, respectively. Life expectancy also differs among the 28 member states of the European Union: it was 81 years on average but ranged from 69 to 81 years for men and 78 to 86 years for women in 2014. Geographically, life expectancy varies from around 83 years in Mediterranean and Scandinavian countries to 79 years in north-western and around 75 in eastern Europe.

The diseases underlying these differences in life expectancy are related to lifestyle, including dietary habits. In the EU, overweight is responsible for around six to nine per cent of cardiovascular disease and cancer occurrence. In the WHO region Europe, the prevalence of overweight ranges from 45 to 67% and obesity from 15 to 30%. Childhood overweight ranges between 18 and over 50%, and obesity from 5 to 25%. On a global level, high blood pressure, tobacco and alcohol account for about 7.0, 6.3 and 5.5% of the global burden of disease (expressed as disability-adjusted life years).

Dietary risk factors and physical inactivity accounted for 10%, with the most prominent dietary risks coming from low fruit and high sodium consumption.

The health gap is not limited to diseases of longevity. Even within Europe, infant mortality rates differ tenfold. On a global level, low and middle-income countries have higher rates of childhood mortality and infectious diseases than high-income countries in Europe. They are confronted with the health implications of undernutrition and overnutrition at the same time, with inequalities differing by socio-economic gradients, gender and degree of urbanisation. In general, poorer diets are observed in younger people and in men.

But are these socio-economic disparities in diet and health really fixed? The facts show that diet and health do change over time in all people, at all levels of aggregation. The trends are slow, but cannot be ignored. Although dietary changes are not easy, either for individuals or populations, they are possible. Dietary habits are dynamic at individual, local, and national scales, right up to the global level. The same goes for socio-economic development: diet and health drifts from undernutrition to overnutrition, infectious to chronic diseases, and childhood mortality to longevity.

The vast differences in dietary patterns around the world do not reflect an inability to change. Changes are possible, and have occurred in Europe. Disease patterns in Europe in the Middle Ages were similar to those found in low and middle-income countries today. Most Europeans were farmers and their daily meals consisted of soup, a little meat, roots and tubers, porridge, bread and beer. Only during the Age of Discovery were products like potatoes, tomatoes and peppers introduced to Europe. Similarly, the past century saw the introduction of Southeast Asian foods and European diets followed trends in the USA. Within Europe, Mediterranean diets are becoming increasingly popular. Diets have changed and foods consumed in every European country nowadays originate from all over the world.

The favourable trends in diet and health are not, however, easily observed within the timeframe and geographic scale of our daily life: dietary changes are closely related to transitions in food systems and socio-economic development. While the difference in life expectancy remains large in the EU-28, it has fallen by 3.2 years since 2002 and the gender gap is also decreasing. At a global level, and in high-income countries, the consumption of healthy items improved in the period 1990-2010, but worsened for unhealthy items, with varying trends seen around the world.

Although it is possible to change dietary habits, it is difficult for individuals to maintain a diet and lifestyle that deviates from the habits in the majority of the community they belong to. Falling back into earlier habits and not maintaining weight losses seems to be the rule rather than the exception. People diagnosed with a pre-diabetic condition, with obesity, high-risk lipid profiles or high blood pressure may be motivated by doctors' advice and dietetic support; nevertheless, many still develop high-risk profiles and require medication throughout their life. Societies with a well-organised and accessible food supply are also confronted with a high burden of chronic disease and associated costs. In Europe, healthcare expenditure accounts for about 6 to 12% of GDP, and primary prevention and health promotion are achieved via lifestyle, social, economic and educational measures.

Just as diets have changed for better or worse over time, so have individuals been able to change their lifestyle, despite the challenges that a complex set of practices related to food and the surrounding community bring. At the same time, it is clear that interventions in the food system are not the only ones needed to improve health. Some of the problems are linked to inequality, housing and even city design. It is this complexity that requires integrated policies and practices to be developed.

Misunderstanding 2:
the government should not interfere in our diet

Consumers rightly wish to autonomously choose their diet, and generally assume that they freely choose their foods and compose their diet. This is not entirely true, however. While most Europeans can afford a diet that fulfils their energy needs, the quality of dietary patterns varies with an individual's socio-economic status. Agriculture, food industries, and national and European governments all interfere with food production and consumption. We live in an 'obesogenic environment' that nudges us, sometimes with sophisticated marketing techniques, into a diet characterised by an overconsumption of calories and specific harmful products rich in sugar, salt and saturated fats, an unsustainable ratio of animal versus plant proteins, and underconsumption of fruit and vegetables. Do we pay the true price of food, and how are food patterns shaped by the food environment and socio-economic factors?

Food insecurity has almost disappeared in the EU-28 where people can rely on a steady supply throughout the year. But not everybody can afford to fill the shopping trolley without concerns. The price of a basket of food varies by a factor

of two or three and tends to be lower in central and eastern European countries and higher in the western and north-western regions, similar to incomes.
On a global level, the portion of household income spent on food ranges from less than 10% in Anglo-Saxon countries to above 40% in the low and middle income countries. The latter cannot afford to spend more, and therefore buy less quality food than the former. In the US the percentage of income spent on food ranges from 10 to 40% for the wealthiest and poorest households, similar to the variation at the global level.These socio-economic differences have real implications for dietary quality. Energy-dense foods contain an abundance of fats, oils and carbohydrates instead of water, but tend to contain less nutrients per amount of energy; moreover, fat and oils, carbohydrates and sugars all have a range of health implications. The nutrient-dense and low-energy foods we need, however, also tend to be more expensive per calorie. Composing a healthy and sustainable diet is more challenging for people with smaller budgets and a lower educational level. To achieve more sustainable diets, the share of animal products and soda drinks needs to be partially replaced by plant-based foods, vegetables and fruits, aligned with continued attention to maintaining food safety. A transition to healthier and sustainable diets might therefore increase consumer prices and might require compensatory measures. Just as agri-food production has secured the food supply, socio-economic measures such as taxes, subsidies and income policies have implications for affordability and access to food. However, there are many socio-economic factors other than economic measures that determine food choice, including education, knowledge and interest in food and health.

The direct social and built food environment is probably equally important as a determinant of food choice. The majority of consumers buy their daily food from supermarkets, which nudge consumers toward products using psycho-social mechanisms, sensory preferences and personal taste and price. The food companies that supply the retail sector are also involved in the processing, packaging and sourcing of foods and commodities from the world market. The network extends to millions of traders and farmers worldwide. Because of these long food chains and governmental interference through subsidies and taxes, the relationship between primary agricultural production and consumer prices is weak, leaving the food environment in the retail space as the pivotal interface for consumer choice.

This discussion shows, first of all, that governments already interfere with the food system and the variables that influence consumers' choices. This ranges from city design and income redistribution policies to measures like setting VAT rates and composing school lunches. In addition, the current markets for food do not work perfectly. Food production, especially at farm level, leads to pollution and contributes to climate change – which all comes at a cost. Food companies and consumers do not pay for that cost, however, and therefore overconsume and waste resources. The second market failure is on the health side: the choices of consumers lead to costs in the health system that are not paid for by consumers themselves, but by governments.

Misunderstanding 3:
the food industry cannot be trusted

The intimate relationship between our diet and well-being requires that we can trust the system which supplies our food through global food product chains. Food is a sensitive topic, almost holy to some and a source of horror to others. Our food has never been as safe as today, yet food incidents, a lack of understanding and the poor transparency of food chains put trust in the food industry under pressure. Given today's challenges on public health and sustainability, the role of food industries and food safety may need to be reconsidered.

Food incidents regularly disrupt consumer trust in the food system. The EHEC outbreak (2011) caused over 30 deaths and several hundred hospitalisations. Creutzfeld-Jacob Syndrome and mad cow disease (BSE) caused few deaths, but generated enormous unrest in society (1992). Apart from these food-borne diseases, dioxins in Belgian poultry, contaminated olive oil from Spain and antifreeze agents in Austrian wine are examples of serious food scandals.

Furthermore, the development of GMOs has led to fears of 'frankenfoods' flooding the market. However, despite these concerns, there is no evidence that products such as modified soy actually have adverse health effects on consumers. In fact, the impact of these incidents leading to distrust in the food system largely exceeds the impact on population health. The societal responses and subsequent course of these crises illustrate how derailments in the food chain can be traced back and lead to direct and sometimes drastic actions. Without a well-organised and industrialised food system, such incidents would likely remain unnoticed and cause large numbers of victims in scattered places and over a prolonged period in time.

Food production, processing and trade are important economic sectors in the EU. In mediaeval Europe over 90% of inhabitants were peasants who first fed their own family and then sold their surplus on local markets. Knowledge and technology have dramatically increased and agriculture in the EU now produces incomparably more (even though it represents just three per cent of GDP). The food supply is not only relevant to the livelihood of farmers, health of citizens and sustainability of the environment, but also to the entrepreneurial activity and economic well-being of many people. Food-related economic activity account for 4.4% of GDP and about 8.3% of total employment in the EU. The sector contributes to self-sufficiency in the EU and to the well-being of its citizens. The economic relevance of this sector is also clear on a global scale. According to the Global Nutrition Report (2016) the annual GDP losses from low weight, poor child growth, and micronutrient deficiencies average 11 percent in Asia and Africa – greater than the losses experienced during the 2008–2010 financial crisis. In other words, private food chain actors and food industries are of considerable economic importance, which puts them in a difficult position when public goods such as food safety and public health are of concern.

Lack of understanding of the food system can cause distrust. Governments advocate healthy diets and lifestyles, while industries seem to be involved in food scandals. Consumers hear promises of wonder diets by self-proclaimed food gurus but know little about agricultural production, food processing and packaging. Along similar lines, citizens express concerns regarding various additives and E numbers. Many of them distrust these 'chemical' terms, leading food companies to search for alternatives without comprising food quality, which potentially increases costs. Another example are so-called ultra-processed foods, which are produced from raw materials that are so strongly decomposed, refined and reconstituted that they are almost unrecognisable in the end product. The view of food as a package of nutrients brought us food technology as well as sufficient and safe foods.

This biochemical conceptualisation of foods and diets may be a corollary of the successes of nutritional sciences in the early 20th century, i.e. the discovery of proteins, carbohydrates, vitamins, minerals and fatty acids. Once labour costs became high, the food industry developed along similar lines, resulting in highly standardised products with constant quality and high safety, which also benefitted consumers by substantially reducing the time required for food preparation. But are they real food?

Today's societal challenges call for rethinking the concept of food safety and food processing. There was a drop in nutrient deficiencies and an increase in non-communicable diseases in the rich world during the 20th century, and this is spreading to low and middle income countries. This means that discussions on food and health cannot be confined to food constituents, contaminants, microbial risks and the like: they must incorporate low-risk and long-term adverse effects that affect large parts of the population and contribute to the burden of disease. Moreover, the food system should move away from indulging our basic apparent preference for fat, sugar and salt and reduce its reliance on food refining technologies. Instead, it should provide minimally processed or whole foods that match the physiological functions of chewing, swallowing and digesting.

The role of food industries, however, is not limited to defining product characteristics and satisfying consumers. Farming activities and food industries are private enterprises and their activities often straddle national borders. Food industries optimise their processes by supplying and controlling worldwide food chains and they negotiate with public agencies about product regulations, investments in factories, office locations and employment opportunities. As long as costs are involved, economic principles provide feedback to optimise processes. Adequate economic feedback loops can be a basis of trust in the private food sector. Effective feedback mechanisms for consumers are, however, lacking: for instance, there are no procedures to control the effects of food production on labour conditions in distant low and middle income countries, on land use and biodiversity, animal husbandry and greenhouse gas emissions, and on other social and ecological issues. A similar reasoning applies regarding health, with several actors being paid to cure diseases, without there being a feedback loop for preventing disease and promoting health. Another new challenge for the food system therefore is to create public and private initiatives that make environmental sustainability and health profitable and trustworthy to both the food sector and public health sector.

Misunderstanding 4:
shorter food chains are healthier and more sustainable

Food can remind us of our roots in nature and modern citizens tend to experience nature as friendly and relaxing. It is tempting to connect our experience of well-being in a natural environment to healthy diets and sustainable foods. Of course, our human habitat is highly artificial and it would be impossible for most of us to survive in a truly natural environment. But is it healthier to obtain our foods directly from nearby farms? And is this also better for nature itself, for future generations, and the future of our planet?

From an historical and ecosystems perspective, human health and well-being are in a continuous balancing act with the natural environment. Food originates in nature, from plants which transform solar into chemical energy and from animals which graze and feed on these plants. Food chains evolved in mutual interaction with socio-economic developments and technological innovations in agriculture, food processing, distribution, preparation and consumption. Plants and animals have been domesticated since the start of the agricultural revolution around 10,000 BC, among others in the Middle East. Hunter-gatherers turned into shepherds with herds, and early agricultural settlements and villages developed. In Europe, mediaeval cities depended largely on rivers to bring food to the market. Eventually, railroad networks and highway infrastructures distributed food and drink to citizens. Farmers and small enterprises such as mills, bakeries and brewers developed into cooperatives. Food companies organised food processing and distribution to supermarkets. In Europe the agricultural and food system evolved from the local to the national and EU level. Food systems are now globally diverse and connected. Despite the apparent disconnection from our natural roots, these developments have brought food security and prosperity to Europe and large parts of the world.

Is a shorter food chain, with food obtained directly from the farm, healthier? Health-conscious people may enjoy visiting farms and appreciate the variety of tastes, but the nutritional composition is often basically similar to comparable foods from a more distant source, or even processed foods. Although organic foods have become popular among the better educated, there are no strong reasons to believe that they are healthier. Any benefits tend to be related to the fact that they are whole rather than refined foods. And they need to be more carefully managed for safety. Moreover, people who eat organic foods may make better choices, more in line with recommended diets, elsewhere, too, and may therefore generally be healthier regardless of the organic status of the food they consume. Feeding whole cities with organic food sourced from the immediate surroundings is virtually impossible in densely populated areas. Imports of feed and food are a necessity, sometimes over large distances, and with technologies that can maintain quality and ensure preservation and safety.

Is a shorter food chain more sustainable? Discussions on food miles made many people believe so, but in reality food transport does not add much to the environmental impact of food production. What is sustainable depends on local natural circumstances and practices, which determine yields and efficiency. The sustainability of food production depends on the quality of the soil, its mineral balance, and a proper use of dung and fertilisers which prevents the eutrophication of water. Regardless of where it takes place, animal husbandry contributes substantially to greenhouse gas emissions, although it does provide nutritious products. Cows and other herbivores may easily be kept on peat grounds or on hills and mountains, whereas feed or milk products may have to be imported in other areas. But there are also risks which relate to location. Keeping cows and chicken outdoors can increase the risk of infections such as bird flu; furthermore, farms may contribute to zoonoses and the overuse of antibiotics may cause them to become ineffective by making certain bacteria resistant (like MRSA). Long and

global food chains, however, also bring challenges with respect to sustainability. In low and middle income countries an increasing part of the rural population cannot make a living from agricultural production. If labour conditions are safeguarded, the production of palm oil for human food and soy for cattle can provide a living for farmers, but also lead to overuse of the land and destruction of valuable natural habitats.

In western societies, farming and agriculture around urban settlements is of interest for a number of reasons. Parks and rural environments have recreational value for the inhabitants of urbanised societies, as do allotment gardens and urban agriculture. This provides opportunities for creating healthy environments that allow physical activity and relaxation, as well as education, teaching and increasing awareness of our links to nature and of the importance of maintaining them sustainably for future generations.

In conclusion, whether short or long food chains are preferable depends on socio-economic development, urbanisation and globalisation. Longer food chains bring food security, diversity, safety and health to people, but require good governance to enhance environmental sustainability and mitigate global inequalities. At the same time, while short food chains do not improve health and sustainability per se, they may provide opportunities to involve citizens and restore trust in the food system.

Misunderstanding 5:
diet doesn't matter, it's all in the genes

Despite the clear relationships between diet, socio-economic factors and public health, individual diets have limited predictive value for individual health. It is almost as if it does not matter what we eat: even people with healthy diets fall ill. But is our fate determined solely by our genes? Does diet not matter?

The deciphering of the human genome and the growing understanding of its relations to the proteome, metabolome and microbiome make it tempting to believe that inherited genes are the major determinants of individual health. But the real story is more nuanced. The apparent disconnection between individual dietary habits and disease outcomes originates in evolutionary principles, which support the survival of the species Homo sapiens as a whole while maintaining genetic variability between individual people. Genetic variation enables our species to reproduce and survive in changing environments, but it weakens the associations between specific foods or nutrients and health outcomes at the individual level. Regarding genetic background, studies on Japanese and Polish migrants to the USA, for instance, have shown that they (or their offspring) gradually adopt the disease patterns of the new host country as they adopt the lifestyle. Diet is clearly an important factor, but nature maintains large genetic variation between people within populations. As a result, the health effect of diets differs between individuals depending on the genetic factors that affect their physiology and biochemistry, and their metabolic, sensory and cognitive system. For each individual, therefore, inherited genes and inborn susceptibility interact with dietary (and other) exposures, or the exposome. During the course of a normal life, many small dietary and genetic effects interact with each other in a sophisticated interplay, and each effect is likely to be small. Taken together, however, they accumulate and change our physical fitness and resilience to new exposures until the weakest part fails. We can learn the importance of dietary patterns by studying groups of people and we can learn about genes by studying genetically related people. Eventually, in-depth research on both diet and genes may lead to personalised diets that are optimised for individuals' genetic make-up. For now, dietary advice realistically accounts for biological (genetic) variation by focusing on nutritional needs and food habits that are adequate for the majority of the population.

The evolutionary principles are also deeply rooted in our behaviour. A baby drinks breast milk, experiences satiation and is pacified and falls asleep, until hunger stimuli return. The physiological needs and psychosocial rewards guide behaviour in a targeted and effective fashion. Even today, the last hunter-gatherer tribes use food mainly to prevent hunger, certainly, but also to maintain the social cohesion of their tribe. When children grow older, they become disconnected from breastfeeding and city dwellers similarly become less connected to food production. Hunger, food shortages and poverty become less important determinants of what, when and where we eat and drink. Learned habits, largely unconscious, and social contexts increase in importance and our dietary choices become less dependent on our inborn physiological needs. We inherited taste and programmed preferences, and learned behaviours. This worked well for us as a species, we grew older in better health. The basic genetic and physiological mechanisms of hunger and satiation, together with inborn or learned preferences for sugar, salt and fat, were essential to growth, gathering of foods and water, and hunting, which in turn allowed us to reach reproductive age and transfer these basic skills to the next generation of *Homo sapiens*.

We have learned to prefer fat, sugar and salt based on evolutionary and cognitive mechanisms. Although initially relevant to the survival of the species, these

preferences and learned behaviours are not necessarily crucial for our species once we survive past reproductive age. We can get food with little physical effort and at low prices on almost every street corner or delivered at home. It can be hard not to give in to the pleasures of tasty, crunchy food, or delicious fluids that are swallowed without even chewing. We have overcome food shortages, but the basic physiological and learned mechanisms apparently are not sufficient to remain healthy in the long run. Preventing age-related diseases and healthy ageing requires advanced insight into the intricacies of the digestion of foods from meals and the metabolism of nutrients and non-nutritive constituents. It requires that we exploit the beneficial nutritious and physiological effects of the diet and we prevent the age-related accumulation of many small adverse exposures. While the basic physiological mechanisms do not automatically guarantee ageing in a healthy way, learned behaviours – mediated by psycho-social mechanisms – can be adapted in a much shorter timeframe than our evolutionary inheritance. Both culturally inherited and scientifically gained knowledge are required to recognise the subtle mechanisms that guide the physiological triggers and behaviours that enable healthy ageing.

Evolutionary mechanisms have therefore gifted us with a robust and adaptive physiology that permits us to survive as a species while also maintaining genetic variety between individuals. And this is how it has to be, given that our diet and environment change between places and time periods. The worldwide diversity in dietary patterns shows that people can feed themselves in many different ways. We are omnivores, adapted to consume any mix of plant and animal foods that contains enough fats, carbohydrates and proteins to provide energy to actively gather food, as well as a variety of vitamins and trace elements to support our biological machinery.

Many food patterns suffice for survival of the species, but global socio-economic differences in life expectancy show that they are not all equally beneficial for longevity. At the level of the individual, food must be varied enough to meet all nutrient requirements; once these are fulfilled, no single superfood or magic bullet can promise longevity. Moreover, people differ not only in their nutrient requirements, but also in the inherited and acquired biochemical pathways and subsequent susceptibility to develop chronic disease. Long-term health implications differ even between people who eat the same food, and differently composed diets may lead to the same diseases. Genetic variants can have decisive effects on health outcomes and high-risk profiles and diseases run in families. Though clinically highly relevant, these genetic variants, just like any essential nutrient, usually explain little of the variation in risk between most people.

At the individual level, the effects of diet on fitness, health and well-being remain largely unpredictable, as drinking, physical activity, smoking and other lifestyle factors interact with dietary patterns and genetic make-up.

Even so, for humankind as a whole, there are clear patterns as to what constitutes a healthy diet. With few exceptions, increasing the intake of a single nutrient or food has limited effects. When ‘better’ options are combined within a diet, however, these foods and nutrients add up and interact to support fitness, maintain health and provide longer life.

So, is our health programmed in our genes? No, and it cannot be found in any single nutrient or food. Health and longevity are linked to the accumulated interactions of nutrients, foods and physiology during the course of a person’s life. What makes a healthy diet depends on a person’s age, is learned by natural and scientific experiments, and is transferred as learned behaviours through the socio-cultural dimension of society. This learning process is ongoing, and as a society and as citizens we need to continue to build on what we know.

Societal and scientific challenges

Having identified drivers for innovation and discussed misunderstandings that could misdirect the innovation process, it is time to look at the optimal direction of innovation. This chapter reflects on the societal and scientific challenges concerning life sciences, the environment, social inclusiveness, and dietary change. These come together in examples of trade-offs and synergies that are relevant to the food system as a whole. Suggestions for a food and nutrition policy will be put forward in the next and final chapter.

Life sciences and health: dietary quality

From an biological perspective, the quality of an organism's diet defines the boundaries within which it can grow, reproduce and enjoy a healthy lifespan. Dietary quality represents the ability of a diet to enhance public health and life expectancy. It is therefore relevant to recall that health was initially broadly defined by the WHO not only as an absence of disease, but also as physical, social, and mental well-being (WHO, 1948). After the rise of non-communicable diseases in the second half of the 20th century, it gradually became clear that this static definition was no longer fit for the purpose of controlling and reducing the spread of chronic disease. (In environmental sciences, health as pertaining to ecosystems has been defined as 'the capacity of a complex system to maintain a stable environment within a relatively narrow range'. In 1984, the WHO also proposed a dynamic definition of human health, formulating it as 'the extent to which an individual or group is able to realise aspirations and satisfy needs, and to change and cope with the environment' (WHO Health Initiative, 1986). More recently, Huber (2011) defined health in the broad sense as the ability of a system to adapt and to self-manage, and this characterisation can equally apply to physiological, social and mental traits in individuals, societies and global food systems. So, rather than fulfilling a set of fixed criteria, health has to do with the dynamics of change and the resilience & ability to adapt of individuals, societies and the earth. However, it remains necessary to define the conditions within which life can be sustained, and how lifestyles and society can flourish within evolutionary and planetary boundaries.

The first challenge regarding food, nutrition and health is to account for the evolutionary boundaries that govern human physical life and longevity. In its early days, nutrition science related nutritional deficiencies to major food groups and explained them by chemically defined components. Sailors travelling far distances were protected from scurvy by citrus fruits rich in ascorbic acid, and beriberi in Indonesia was prevented by the consumption of unrefined rice containing thiamine. Numerous essential nutrients have been identified based on their causal relation to functional biomarkers and risk factors. These intake requirements are used to evaluate the quality of the diet and the nutritional health of various population groups. There are clear constraints related to the essential nutrients of a healthy diet, but they represent only a partial view of diets and foods in relation to health. The health implications of a diet are more than the sum of the effects of the nutrients it contains. Food groups, interactions and non-nutritive compounds play an equally important role in sensory and psychosocial preferences and rewards, physiological limits, digestion, bioavailability, gut flora, satiation, etc. Relatively little is known on the short-term effects and regulation of food, digestion and health through processes such as physiological, metabolic and psychosocial feedback and reward mechanisms, which regulate energy balance and nutrient intake via our meals, snacks and drinks. The simple nutrient perspective on a healthy diet must be replaced by a comprehensive food perspective that takes into account the physiological effects of foods, meals, diets and food systems, and provides a thorough outline of the space in which food-based dietary guidelines can be formulated.

A second challenge relates to ageing. Most of us pass the evolutionary boundary of reproductive age. What are the physiological requirements for ageing humans? Physiological nutrient requirements differ during pregnancy, lactation, childhood and adolescence and by level of physical activity. For adults and the elderly, nutrient requirements are largely based on maintaining a healthy nutrient balance, with extrapolations to other age groups based on body composition, energy needs, animal experiments and metabolic pathways. For disease prevention, however, dietary guidelines are largely based on epidemiological research into foods and nutrients as related to overweight and obesity, biomedical risk factors and the occurrence of chronic diseases. Biomedical and pathophysiological research provides evidence on the necessary causes of disease that can be generalised to humans, and the concept of defining essential nutrients necessary to prevent the clinical manifestations of deficiencies follows conceptually similar lines of reasoning. However, diseases can be prevented and public health promoted through dietary habits, which represent a modifiable set of factors (or component causes) relevant to longevity and quality of life.

Preventive dietary measures that address these component causes jointly are therefore likely to provide a more effective means to inhibit detrimental cause-effect sequences and improve public health in society. Unlike traditional fundamental research, this requires a transdisciplinary and integrated view of the full body of scientific evidence and the societal context.

Fundamental research also generates knowledge that is important to facing challenges related to improving health in an ageing society. For instance, new molecular and medical technologies offer ample opportunities to better understand feedback mechanisms that regulate the interaction between foods and nutrients on the one hand and the functioning of cells, tissues and organs on the other. This fundamental insight is essential to answering questions on the evolutionary programming of our metabolism, pathophysiological processes and health & disease over the long run. In the domain of human behaviour, sensory and neurocognitive processes may lead to better understanding of the preferences programmed in our brains. Understanding these processes could lead to scientific breakthroughs that can help optimise metabolisms and food choice, which could open up new pathways to improving dietary quality and food habits among citizens and in clinical settings.

Planetary boundaries: environmental sustainability

Evolutionary processes operate within limits set by the global environment. Not respecting these limits can only negatively affect the well-being of the human species on the planet. Population growth and climate change, for instance, are relevant to the planetary limits. Europe and the USA constitute a relatively small and stable part of the world population, whereas the populations of Asia, Africa and South America will continue to grow until the world contains an estimated nine billion people in 2050. The growth of populations and economies will place additional burdens on planetary resources – especially due to the demand for protein from animal products – as is already the case in developed countries. Currently, protein production and intake per capita are, on average, sufficient to feed the world. Producing sufficient and high-quality proteins and nutrient-dense foods for nine billion people will be a challenge, however, especially if it includes a transition to plant proteins and a more equitable distribution among people. Intake of animal sourced proteins already varies greatly around the world and demand will increase with population size and longevity, socio-economic development and urbanisation. Mitigation strategies based solely on increasing production without addressing dietary patterns are unlikely to be beneficial for public health.

Climate change will affect the productivity of great swaths of the earth, with a shift of food production away from the equator. Food security and nutritional & dietary quality will require more efficient use of arable land and water resources. The nutrient cycles of substances such as carbon, nitrogen and phosphorus need to be closed to diminish losses and stop global warming. The circularity of food chains must become a rule rather than an exception: this will require investment in resource-efficient production, processing, distribution & preparation, and diminishing of food waste. Currently, agriculture produces some 24% of total GHG emissions, and animal production (including animal feed) accounts for about 2/3 of these emissions. It has been estimated that these GHG emissions could be halved by optimising animal production and breeding; further gains may come from capturing carbon from the air and closing the carbon cycle. Regarding diets, it has been estimated that a transition to more plant-based food patterns could reduce diet-related GHG emissions by about one third. Although only a small percentage of global greenhouse gas emissions originate in plant production, a shift towards more plant-based diets should include a critical evaluation of the production of crops, fruits and vegetables. Greenhouses themselves are highly resource-efficient production systems, sometimes even more so than the (unstandardised and dynamic) open field. Robots and precision agriculture may improve efficiency and yields on arable land. In addition, the food system itself comprises many intrinsic relationships. For instance, cereals provide high quality proteins, but almost 70% of the biomass does not end up in the grains consumed by humans, instead remaining in the food system as animal feed. Reducing livestock would require that such residuals find other valuable applications.

Land use, soil quality, water and biodiversity also need attention from an ecological point of view. Plant proteins from soy, lentils, beans, peas, etc. may replace proteins from animal sources while also improving soil quality by nitrogen-binding. But soy and palm oil production can also damage landscapes and negatively affect the habitat of animal and plant species, putting biodiversity at risk. Soil quality can be maintained by balancing the use of dung & fertilisers and preventing the pollution of surface water and algae blooms. Similarly, to safeguard marine fish stocks, fish farming may gradually replace caught fish, just as livestock farming has largely replaced hunting; but like animal farming, this can lead to major environmental pollution.

In addition to these resources, the food chain itself also requires attention. For instance, food processing may need to develop less water-intensive technologies and food packaging has to find a better balance between waste reduction, lengthy transport distances, shelf-life and food quality. To minimise losses and arrive at a

circular food system, these aspects need to be considered simultaneously, and synergies and trade-offs must be evaluated, both globally and locally, in the public and private domain.

Socio-economic disparities: social inclusiveness

Socio-economic disparities in diet, nutrition and health are a rule rather than an exception: there are major differences. The variety in diets between people, countries and continents, the trends in per capita food consumption, and successful interventions in risk groups and clinical contexts show that the dietary behaviour of populations is largely shaped by socio-economic development and urbanisation.

There are socio-economic disparities both within societies and between them. The demand for cheap labour, as well as armed conflicts and crop failures which affect food and nutrition security, are socio-economic drivers of migration. Eventually, they contribute to both socio-economic inequality and the cultural enrichment of the host country. From the perspective of the global food chain, social inclusiveness entails safeguarding the livelihood of farmers & enterprises and their food & nutrition security, and involves governments and multinationals in shaping the

socio-economic context for food production and consumption on the global market. Ultimately, the human right to an accessible and affordable diet, along with economic development, should drive the global food agenda.

But who decides which disparities are acceptable to society? And what values should underlie our mitigation strategies? The freedom to choose food is perceived as a social right and as an individual responsibility. Public policies strive to safeguard food security and avoid direct interfering in consumer choice in supermarkets and in their consumption of food at home. At the national level, public health policy measures can be ranked from least to most coercive. The more intrusive the state becomes, the stronger its justification has to be. This is in line with a market-oriented view which assumes that costs of food production and unhealthy behaviour are all born by the consumer. This is not the case in reality, of course, as public authorities do interfere in the food system via food policies. Examples include subsidies for farmers, trade conventions, income policies, food taxes and health insurance. These remove some of the costs of a dysfunctional food system from individuals and bring them into the public domain. This is noticeable to individual citizens through food labels and logos on food products. It is also visible in general food-based dietary guidelines. Usually, these approaches focus on nutrients, as most citizens struggle to fully understand complex diet patterns. The overall result is that dietary quality and health are clearly correlated with socio-economic status.

Adding dimensions of environmental and social sustainability, fair trade and animal well-being makes this undertaking even more daunting. The search for simple but effective heuristics for proper meals and dietary habits is rather complex, leaving consumers to fend for themselves. The individual-centred market orientation suggests that technology-driven personalised nutrition approaches could be a way out, especially if combined with factoring environmental costs into the price. Although personalised nutrition can add value for some population segments, it needs to factor in the socio-economic dimension, and personal feedback must be brought in line with scientific insight into planetary boundaries and the circularity of the food system. Sustainable food-based dietary guidelines should be the basis of all dietary guidelines. This has been denoted as the SDG² approach, as it simultaneously addresses the Sustainable Developments Goals and Sustainable Dietary Guidelines.

Food environment: dietary change

For most consumers, food labels, logos and food-based dietary guidelines (FBDGs) can be difficult to notice due to the preponderance of other sensory triggers, such as packaging, display and pricing in supermarkets. For instance, in the UK the money spent on advertising fruits and vegetables or better eating was less than three per cent of the total amount spent on commercial advertising for food and drinks. Changing the lifestyles of individuals by just providing information is notoriously difficult, if not impossible. Attention is therefore shifting to nudging people toward a healthier lifestyle by changing the food environment. Different environments lead to different behaviours and health outcomes, which is more easily seen if we expand our perspective from the individual to the societal and global level. People adopt and adapt their lifestyle to their social and built environment. Moreover, the effectiveness of interventions depends on complex interactions between the demographic, social and economic background of the target population.

Dietary choices have major effects on both public health and the environment. Just like healthy diets, the climate challenge has real implications for people's diet patterns. It has been estimated that diets low in animal products could eliminate 25-30% of the food-related emissions of greenhouse gas. But trade-offs may be necessary between health and environmental values. Economic growth in Africa and Asia, for instance, is creating large socio-economic middle classes, which are catching-up with western diets and increasing their consumption of protein from meat. Decreasing meat consumption may make western societies healthier, but some increase in the consumption of animal products could have health benefits in

the lower socio-economic strata of many low and middle income countries. From a health perspective, reducing meat consumption in developed countries could initially improve the fat profile of a diet, but at a certain point lower availability of B-vitamins & iron and decreased protein quality may negatively affect the nutrient adequacy of the diet as a whole.

Despite socio-economic differences, citizens can be involved in societal processes and agenda setting. Information, personalisation and empowerment of people are needed to support the required shift in diet. Within the social and budgetary constraints of their lives, people freely choose their diet and lifestyle, for themselves and for their close relatives. Less healthy foods rich in saturated fats, salt and sugars eventually tend to become more prevalent in the diets of people in lower socio-economic classes, and they may be the least sensitive to changing dietary habits. So-called personalised nutrition programmes are advocated to support changes in diet, but for the moment such approaches are probably more effective at improving the food habits of higher rather than lower socio-economic strata. Although such ICT technologies may be valuable in clinical settings and for research, they are unlikely to become effective mitigation strategies for the socio-economic disparities in diets.

Synergies and trade-offs: the food system

There are many societal challenges linked to the food system as a whole. These relate to the life sciences, planetary boundaries, socio-economic disparities and consumers' food environment. Moreover there are knowledge gaps on policies, strategies and technologies that hold back the transformation to a sustainable, secure, safe, social and healthy food system. Food and nutrition policies need to build on solid evidence and create synergies between health and sustainability objectives. It is unlikely that a policy that advocates small incremental changes will be effective. The change from animal to plant based foods and reducing waste is a major systems change, built on diet quality and public health principles: improving the nutrient density of food by increasing the amount of fruit and vegetables; maintaining energy balance by eating low-energy foods and increasing the levels of physical activity; and reducing the consumption of salt, sugars and saturated fats.

The primary pathways for this systems change are in the social and economic domain. Potential solutions in the food chain and food environment need to be evaluated for trade-offs and synergies within the food system as a whole. Here we illustrate some of these interdependencies.

As an example of synergy, it appears that a transition from animal to plant-sourced proteins could be accompanied by gains for both public health and environmental sustainability: the challenge will be to develop profitable business models that can support this transition. Plant-based milk and meat substitutes are existing examples, and potential future protein sources for animal feed and/or human food consumption include algae and insects.

A second example of possible synergy relates to the social domain. In some places, local farms have developed business models for elderly care, while others have introduced cooperative ownerships with nearby city neighbourhoods, fresh food delivery systems or close relationships with school-based education projects. Although such initiatives cannot suffice to feed the cities at large, they may help build relationships between local farmers and urban citizens, link people to their roots in nature, restore consumer trust and educate future generations. In principle, farms can develop local food chains with local businesses, and school programmes with community health services.

Third, connecting food production with public health can create synergies. Public expenses on health care are enormous and the medical profession serves as a trustworthy source of information, but little is invested in preventive health care; the private sector spends enormous amounts on advertising, but this is not perceived as an independent source of information on health and sustainability. If dietary health and sustainability can become profitable issues in the commercial domain, this could be advantageous for society at large. This is clearly not a quick win, but if it can be done based on public and private evidence and without compromising trust, the benefits can be substantial.

Trade-offs, which tend to point to the need or potential for innovation, can also be envisioned. As a first example, if meat intake is reduced below certain levels, the overall intake of iron & vitamin B12 and the quality of protein may become too low. We should not trade such nutritional inadequacies for sustainability. Vitamins are therefore already added to products such as soy-based meat substitutes. Alternatively, fertilisers could be used to ensure a certain content of elements such as selenium and zinc, and plant breeding could focus on variants that accumulate bioavailable trace elements (e.g. selenium and zinc) or efficiently produce vitamins (e.g. 'golden rice', 'yellow cassava'). Such technology-driven strategies must be closely matched to the livelihood of primary producers, the actors downstream in the food chain, and the nutrient needs and food habits of consumers.

As a second example of a trade-off, we have to ask ourselves whether we should exchange autonomy for sustainability and public health. Food is wasted at the end of the pipeline and the economic burden of healthcare is high for society. We are used to preparing our foods in the kitchen or having it served according to our wishes in a restaurant. Food waste is caused by food improperly kept outside the refrigerator, cooked in too much water (requiring excessive energy); in the social domain, ample food portions are a sign of hospitality, friendship and wealth. Is our inherited food and health culture fit to face today's societal challenges? In wartime, food was rationed and centrally provided. It might indeed be more resource-efficient to use similar schemes for catering or central kitchens with a more restricted (although pleasant) menu. In recent years, charities and churches have provided foods that are about the expiry date to socio-economic disadvantaged people. In other cultures, citizens from all social classes get their meals jointly from a central kitchen as part of their cultural and religious system. Our society has focused on two-generation households in a free market context, at the expense of social interaction and sustainable preparation. Given the food system challenges, it might be time to rethink the system, raise awareness and experiment with alternatives.

Third, the transition of the food system also requires a transition in the research and science that underpin it. The scientific community has differentiated into disciplinary communities, to publicly funded academic and privately funded contract research. This fragmentation and inefficiency in the use of data, tools and models has to be overcome if we are to facilitate breakthroughs that can help reform the food system. The scientific community needs incentives for data sharing and transdisciplinary research, which requires new contracts between public and private actors in agriculture, food companies, consumers and policy makers.

Towards a European food, nutrition and health policy

Given the societal challenges concerning dietary quality, public health, sustainability and social inclusiveness, it is necessary to transform the food system. As indicated before, the relevance of this ambition is globally recognised in the SDGs and the Paris Agreement. Europe can underpin its contribution to this process via expertise gained in the Common Agricultural Policy and can build on EFSA's nutrition expertise. Starting from the Food2030 agenda, EU policy goals for food, nutrition and health should include balanced and sufficient diets for all citizens, reduced environmental impact (both in and outside the EU), viable and socially balanced agri-food business (in and outside the EU), and contributions to global food security through socio-economic connectivity.

These objectives must be realised within a single generation, which will be a unique and unprecedented social and cultural experiment. The transformation cannot be repeated and must secure a sustainable outcome. It will require many consistent and mutually reinforcing steps that coherently point into the same direction, and that account for multiple societal drivers and diverging (short-term) stakeholder interests. Where governance is concerned, the European subsidiarity principle should ensure that decisions are taken as close to citizens as possible and that the EU does not take direct action (except in the areas that fall within its exclusive competence), unless this is more effective than action taken at national, regional or local levels. Guaranteeing public health requires measures at the national level, which can be based on the principles of the 'intervention ladder', under which stronger justification is required for more coercive or intrusive measures.

In other words, what can be done at a member state level should be, and intervention strategies should not be more intrusive than strictly necessary. These governance principles require the alignment of policies and engagement of food system actors and society. They should use all the available knowledge on the European food system in its global context, be aligned with national and regional policies on food, nutrition and health, and involve public and private food chain actors. Is it possible to outline the remits and boundary conditions for such a policy?

Policies for public health & sustainability

Public health and sustainability are intrinsically connected through the food supply chain and its actors in the food system as a whole. The relationships between diet & health and between agricultural production and food are rooted in the biomedical and biological principles of the life sciences.

The first remit of the European food and nutrition policy is to address dietary patterns as the common denominator of both public health and environmental sustainability. Public health outcomes can be defined and the sustainability of the food supply chain promoted based on dietary patterns.

The term public health encompasses the physical, social and mental well-being of citizens, not just the absence of disease. From a nutrition perspective, the relationship between diet and health is often framed in terms of nutrient deficiency, food safety and patho¬physiological mechanisms of diet-related diseases. In this sense, diet quality is evaluated in terms of microbial and toxicological risks, as well as nutrient requirements established by EFSA. At the food level, these are translated into food-based dietary guidelines drawn up for the citizens of EU member states. Nevertheless, micronutrient deficiencies and food safety issues continue to affect vulnerable people, and low adherence to food-based dietary guidelines and a high prevalence of chronic disease show that dietary quality is still a long way off. Current knowledge suggests that policy targets for the diet should emphasise a reduction in saturated fats, sugars and salt as a direct outcome and that the dietary pattern must contain a larger share of nutrient-dense, fibre-rich and energy-poor foods.

The share of GDP spent on medical care and economic losses due to unhealthy diets are likely in the same order of magnitude, but not simply exchangeable. Healthy lifestyles can prevent or postpone the need for drug treatment of conditions such as high blood pressure or lipid profiles and can help mitigate the detrimental effects of obesity on chronic diseases like diabetes, heart diseases and cancer. To achieve these more distant public health outcomes, dietary patterns need to be evaluated for their effects on fitness & long-term energy balance (BMI), perceived health & well-being, life expectancy, and disability-adjusted life years, including the resulting costs of health care.

The sustainability of diets refers to their embedded environmental effects, which originate from agriculture, food processing and other stages of the supply chain. As for public health, the dietary quality of the pattern determines what needs to be produced, be it in or outside the EU member states. Achieving sustainability in the food system as a whole must become a key objective of the European food and nutrition policy. Increasing the intake of plant protein at the expense of animal protein is one of the key challenges as it is related to issues such as GHG emissions, land use, soil mineral balance and eutrophication. Minimising waste in the food chain and by consumers is another big challenge: the food chain requires that policies addressing the agri-food industry be formulated at the European level, while policy affecting consumers directly should be made at the national level. Improved environmental sustainability is partly linked to healthier dietary habits. An ecologically sustainable food system requires a major shift towards nutrient-dense plant-based diets with considerably less animal-sourced foods. The emphasis on both health and sustainability as remits of policy should initiate a shift within the food production system that emphasises foods and dietary patterns instead of nutrient content alone.

Policies on healthy and sustainable diets must reconsider the time dimension of agri-food production and healthy ageing. Current incentives on ‘care and cure’ should be balanced with incentives that promote healthy lifestyles and a sustainable environment. This requires a paradigm shift from focusing on treating disease in individuals in medical settings to looking at ways to prevent disease through sustainable and healthy food production that makes the most of the social and built living environment of EU citizens. Consumer behaviour is the cornerstone of sustainability, public health and economy. In the domain of public health, this holds for both food safety and disease prevention. In a short timeframe, consumers would benefit from improved food choice and diet quality by gaining in fitness, well-being & social connectedness, energy balance and an improved BMI. Over the lifetime, high dietary quality contributes to healthy ageing and reduction in the risk of chronic disease at the national level. For the next generations, the appropriate changes in global agri-food production would contribute to a sustainable and safe supply chain, with public health gains that cannot be achieved by changing consumer behaviour alone. In this long-term systems perspective, society benefits from economic prosperity and improved public and environmental health throughout the lives of its citizens, while Europe as a whole benefits from a flourishing agri-food sector and contributions to food security. The proposed foundation of a common agricultural and food policy have been discussed in a separate document.

Consumer policy and the food environment

The evolutionary and planetary boundaries of human diets and agriculture, social and economic inclusiveness are key for sustainable development of the food system. Apart from economic growth, it needs to ensure that we reach the people who are most vulnerable in terms of the life cycle and their socio-economic position. The food system brought a high level of food security, dietary diversity and nutritional quality, sufficient for most stages in the life of a person. Without it, health and well-being would most likely be at a much lower level in the EU. A sustainable food supply is a prerequisite for public health, i.e. the 'science and art of preventing disease, prolonging life and promoting health, through the organised efforts of society'. Related to this, health promotion focuses on 'the process to enable people to increase control over their health and its determinants, and thereby improve their health'. Building on these concepts, policies to enhance healthy, safe and sustainable dietary habits should reach EU citizens in their daily food environment. Consumers fill their shopping baskets based on conscious or unconscious responses to triggers in the social and built environment. Could they instead become partners in the transition towards a healthy, safe and sustainable food system? Food and nutrition policy operate within the social and built environment, where people go to school, work, eat & drink and enjoy leisure time. Short-term physiological, psychosocial and financial rewards are key drivers of food choice, easily overruling knowledge about long-term risk reduction and environmental sustainability. Dietary quality diet originates in a diverse, safe and sustainable supply chain, but can only be widely adopted if citizens are enabled to navigate the surrounding social, built and economic food environment.

Social inclusiveness is a key asset in a healthy and sustainable food environment. It relates to disparities between people and to solidarity with future generations. It is concerned with the livelihood of people in global agriculture as well as ethnic and cultural minorities, often in the lower socio-economic segments of society. Food and nutrition security is intrinsically related to humanitarian and ethical values. But food not only connects people: it can also separate them. Cultural exchange & migration, and new ethnic & religious groups have diversified the European food culture but they are also closely intertwined with socio-economic disparities.

People talk about food, and often enjoy it together. Social, sensory and aesthetic enjoyment of food is reflected in TV shows, recipes and cookbooks. New habits and foods from globalising markets spread through society via unfamiliar eating cultures and higher socio-economic groups. Exploiting this social and cultural diversity could simultaneously enhance social inclusiveness and eating & drinking

habits. Urban districts and municipalities could support incentives by charities, local churches, food banks and the like to bridge socio-economic gaps between social, ethnic and religious groups in their local community. As intergenerational solidarity is a key asset of ecologic, economic and social sustainability, education and training are the natural pillars of investing in a sustainable food system. Hunger and satiation are inborn but food habits are learned. Eating and cooking habits are primarily transferred within families and peer groups. Primary and secondary education focuses on skills useful to building a livelihood as an adult, but should integrate healthy and sustainable lifestyles for citizens in a globalised world.

A second consideration is that socio-economic factors are crucial to modifying dietary habits. Generally, the well-educated and 'worried healthy' are the first to engage in societal trends towards healthier or more sustainable diets, leaving less-educated and socially less integrated people behind. Education, peers and social networks are key to adopting new lifestyles. Currently, lifestyle advice is based on biomedical and risk factor approaches implemented by nurses, family doctors and community health services, including vaccination, cholesterol-lowering drugs and medical check-ups. Smoking, drinking and physical activity are established behavioural targets in public health policies. Policies against smoking

have helped change social norms; for instance exposing people, especially vulnerable children, to passive smoking is now considered unacceptable. Campaigns against alcohol mention brain development and violence among adolescents to influence social norms regarding drinking. Similarly, reduction of meat consumption and food waste are also subject to ethical norms. To achieve change, food and nutrition policy should recognise that dietary habits represent complex behaviour, with different social norms, attitudes and beliefs for different food groups, meals and occasions.

Third, social media, education and the private sector offer opportunities to engage the present and future generations in the food system transition. Values, beliefs and attitudes toward food are imprinted in childhood and adolescence through numerous implicit and explicit messages from parents and peers, and via retail, food outlets and shopping centres. But dietary habits can change: our habits are certainly different from what they were 50 years ago, for instance. Current policies focus on food-based dietary guidelines, food labelling and logos, apparently without much success. Such approaches target the conscious mind and are useful for planning diets, but they fit less well in the narrow time-window of decision-making by consumers in a tempting food environment. As ICT is gradually being introduced in the food environment, supermarkets, kitchens and classrooms, these technologies can facilitate the adoption of new habits and skills. Beyond the labelling of food products, ICT can provide targeted information on food sourcing, fair trade, animal welfare, sustainability, health, allergies, etc. To teach future generations the benefits of healthy eating, school canteens and outlets near schools should be congruent with educational messages. In schools, a playful approach can convey a certain perception of the food system and enrich children's food preferences and dietary habits with awareness of geography, biology, social inclusiveness and technology. ICT and the emerging Internet of Things today behave like a neuronal network that exchanges information and knowledge between consumers, food companies and the global food chain. However, the data streams and money flow that originate from consumer purchases also represent an information and knowledge advantage that could ultimately concentrate power in the retail and food industry. To safeguard the autonomy and privacy of consumers, food and nutrition policy should protect the ownership of data and financial transactions, and ensure that information exchange is unbiased.

Fourth, the built environment closely reflects socio-economic positions, determines the actual food supply, and nudges people to suboptimal diets. This is closely linked to urban and rural planning: there is a need for new incentives & business models that simultaneously support healthy eating, living and physical activity. This can provide people with a livelihood and create business opportunities in urban development, services by the food sector and leisure services. The actual circumstances, however, differ greatly between regions and socio-economic groups. Such transformational projects therefore require smart matches between citizens and public & private partners, including food labelling and ICT-based approaches. Creating such a food and health environment requires a long-term vision coupled with incentives and supportive policies at the national and city level. As healthy and sustainable food habits flourish in a suitable food environment, urban and rural planning must promote healthy and socially inclusive living conditions. The food environment is already changing and opportunities are emerging. The growth of internet stores and delivery services is altering the function of city centres and shopping malls. In other places, urban farming brings food production closer to the experience of people and engages them further. Alternatively, farms close to an urban environment could join cooperatives of citizens and offer social, educational or care-related services. These developments can create new meeting places with learning opportunities for eating in a healthy and sustainable way. New futures for the food environment should be envisioned involving joint actions between consumers, public and private parties.

Fifth, food prices and household income are limiting factors for a healthy, nutritionally adequate and sustainable diet. Household income spent on food ranges as much between socio-economic strata within countries as it does between countries. Socio-economically disadvantaged people need to be empowered at the national level and require a supportive food environment with access to affordable food that prevents them from falling below a socially acceptable level of well-being. Income is related to social disparities in diet and health, and price is related to food quality. Pregnant and lactating women, infants, children and the elderly are among the most vulnerable people. This implies that income policies and targeted food-taxes could improve the diet of low income and minority groups. However, for addictive behaviours like smoking and alcohol consumption, price appears not to be a strong determinant; moreover, the price elasticity of food products is generally low as well. In fact, eating habits and socio-cultural norms seem to be as important as price and taxes. To be effective, food and nutrition policy needs a coherent and targeted combination of social and economic measures.

In summary, enabling citizens to engage with the transition of the food system requires coherent action in all the above areas. The fundamental transition of the food system should be built on a large series of synergistic developments in the social, environmental and economic domains. The dietary lifestyle and food environment of EU citizens will play a pivotal role in this transition, which will require coherence between EU, national and local policies.

Food systems policy: integrating the food chain and its actors

The government can use its policy instruments to change the behaviour of consumers directly, as suggested above. It would be best, however, to have these measures aligned with similar actions by the retail, catering and food industry. Their influence, through marketing and otherwise, on the behaviour of consumers is probably much stronger than that of government communication, subsidies or taxes. A concerted action to change food practice would provide a fuller range of stimuli to consumers than just a few policy measures focused on consumer information, school food or greening the tax system. At the same time, cooperation with the private sector should not compromise the power of the state to regulate where needed.

Public and private actors have complementary roles in the food system. Consumer trust in public governance & authorities and in private enterprises & food companies differs between different nations depending on their political and economic systems. In western societies, public authorities define policies on safe and healthy foods but are hesitant to interfere with individuals' freedom of choice. Private companies maximise profits through commerce and competing for market share. Together, this public-private interaction has gradually increased and diversified food supply and improved the safety, health and well-being of citizens. In contrast to individual behaviour, the challenge of public health and sustainability requires incentives that cover a longer time span and a higher level of organisation. At the national and local level, public and private sector activities could be stimulated to share best practices and co-create healthier and more sustainable food environments.

For food industries, changing food composition may be an effective strategy. Current strategies address the human inclination to salt, fat content and added sugars in foods. A shift from animal protein to plant-sourced products could improve sustainability, just like improvement of the fatty acid composition of bread spreads contributed to population health. Companies in food processing and retail might benefit from strategies that are built on demand for plant-based protein.

For the primary sector there are opportunities for innovation in food composition. Increased demand for fruit and vegetables helps these sectors in agriculture. If breeders are able to develop new varieties with better nutritional content, institutional arrangements can be developed to co-create specific niches and share the profits with producer organisations as co-owners. In population-dense regions, agriculture around cities can develop metropolitan farm systems that not only produce foods and calories but also actively participate in social and environmental services.

Power relations are an inevitable aspect of the food system. Whereas foods flow from agriculture to consumers, money flows from consumers to food system actors. Most foods are channelled through a relatively small number of international and national retail companies and a number of major European or global food companies, giving them a powerful role in influencing policies and consumer behaviour. Within the limits of global market prices, they set prices and control the flow of food and information to the consumers. The latter is increasingly linked to personalised advertising (e.g. via social media) and invites a discussion on consumer privacy and freedom of choice. As supply and pricing strategies are determinants of food choice, the retail sector and large food companies have developed into actors with an important societal role, and the health and well-being of consumers has become an implied ethical responsibility. Food and nutrition

policy must include corporate social responsibility in retail and food companies to enhance the health and environmental sustainability of the food system. Given the international playing fields of food processors and retailers, and the need to sustain the common market, the EU has a key role to play in food systems policy.

Socio-economic development is connected to disparities in diet and health, and the information revolution is likely to behave along similar lines. Those who control information streams can be powerful actors in the facilitating or frustrating of the transition to healthy, sustainable and affordable diets for all. Food and nutrition policy should challenge the private sector to facilitate the transition through data sharing with public actors and enhancing consumer trust in the food system. This includes not only data on consumers but also on farming, which is increasingly contracted by food industry and retail under sustainability schemes.

Governments should not only work with or against the existing companies in the food chain. ICT companies will become more important: for instance, social media can be used to nudge consumers into more healthy behaviour. Disruptive innovation often comes from new players, who range from start-ups (e.g. in plant-based protein sources aiming to replace meat and milk) to health insurance companies and cities with a food policy. All these aspects of a food systems policy imply that governments have to rethink their policy instruments. This relates to current agricultural policy as well as environmental policy, for instance (e.g. better application of the 'polluter pays' principle), or zoning and fiscal measures. This brings us to the topic of the governance of these interrelated policy domains.

Governance

The societal challenges of global warming, population growth and healthy ageing are intertwined. Transformation of the food system is needed to support secure, healthy, safe and sustainable diets for all. In practice, because economic interests, public health priorities and political realities differ among EU member states, effective governance is limited by a lack of coherency between the directorates general of the EU, the ministries of member states, food chain actors and consumer behaviour. The transformational remit for the food system, however, goes beyond geographical, national or sectoral boundaries and has to integrate biological and behavioural drivers of consumption in the daily food environment of EU citizens, between the agri-food and healthcare sectors. This requires food and nutrition policies to be aligned from a food system perspective. It calls for a multi-levelled approach with ramifications for the actors and beneficiaries in all societal domains. For Europe, this requires governance that accounts for the principle of subsidiarity and the intervention ladder (see introduction to this chapter).

In order to apply these principles, the remits of the food and nutrition policy must be agreed upon first. At the global and European level, the UN SDGs and Paris Climate Agreement represent the first steps guiding European food and nutrition policy towards healthy and environmentally sustainable diets. To advance policies, these commitments need further translation into innovation pathways and mitigation strategies, based on shared objectives and sound knowledge.

As food cultures differ within Europe and health systems are national, there does not seem at first sight much reason for a European food and nutrition policy from the point of view of subsidiarity. This would be a short-sighted conclusion, however, as there are several reasons to act on the European level. The first is that there is already a European food policy with respect to food safety and food labelling. Food is part of the European common market, and many companies in the food industry, retail or food service work across borders. Working with them on a food environment that makes the healthy choice the easy one is probably most efficient at a European level. A second reason is that some measures are easier to take

together. Especially in smaller countries, a border is always near, which means that fiscal measures in just one country (such as taxes or higher VAT rates on sugary drinks or animal-based products) could soon be undermined by cross-border shopping or become ineffective at EU-level because of increasing exports to other countries. It would therefore be simpler to implement any changes together. Where the sustainability of food is concerned, EU standards should prevent a race to the bottom in standards regarding GHG emissions, antibiotics, phosphate use per hectare, etc. The EU also has a role to play in international trade agreements with non-member countries. Burdens should not be allowed to shift to less vocal places, causing carbon leakage, for instance (moving production to less-regulated countries that are less eco-efficient).

Two other reasons why the EU should concern itself with food and nutrition policy are its well-known policies on research & innovation and agriculture. Regarding the former, the EU already includes food policy issues in its research programme under the title Food2030. This helps member states to realise efficiencies of scale and learn from each other's research approaches and results. Concerning agriculture, we argued in an earlier document that the Common Agricultural Policy needs reform to meet challenges in food production and consumption. In the present document, we argue that the food system transition cannot be limited to agricultural production, but should also include food processing, the food environment and a change in the dietary habits of consumers. It should cover the whole spectrum from farm to food, fork and fitness, and must include privately owned food companies and EU citizens as key actors.

Of course, this does not mean that member states have no role to play in food policy. On the contrary, they are probably the single most important level of governance. But there is also a lower level, that of the municipality. Several cities have already formulated a food policy. At first sight that can seem a bit strange: cities do not play a large role in the production of food, and they exist in part to ensure a division of labour with the countryside. But this is very much a view based on calories, not the social and cultural aspects of food. And it is those aspects, higher up in Maslow's pyramid of needs, which are important in the transition to a more sustainable diet. The support of food culture by cities is comparable to subsidising high culture: it helps keep them an attractive place for residents and visitors. Cities also have practical instruments to promote a healthy lifestyle, from shaping the food environment by permits for food takeaway restaurants (in some cases leading to an obesogenic shopping environment) to support for short food chains that link consumers with the green surroundings of the city.

Monitoring and research

Scientific research is a driving force for innovation. Research, however, is mostly organised within disciplines and purposely excludes noise and extraneous confounding factors in order to identify fundamental processes. By now, we are well-informed about the major societal challenges regarding food, nutrition and health. However, mitigation strategies require integrated knowledge based on big data from numerous disciplines, as well as foresight on the part of policy makers to prioritise and effectively implement the most efficient strategies to reach policy goals. Data, metrics, tools and models are needed to monitor and evaluate the performance and innovation strategies in the food system at large, in the consumers' food environment and in the composition of diets. To achieve this, there is a need for incentives to overcome disciplinary fragmentation, improve the efficiency of funding mechanisms, and foster open access to data, information and knowledge.

The transition to a healthy and sustainable food system requires research and innovation by public and private food system actors, as well as the monitoring of progress and unforeseen side effects. The key challenges are in the different time

scales of the transition. This ranges from hours to decades when we consider physiologic satiation and psycho-social rewards, food safety, fitness and nutritional health, disease risk and environmental sustainability. These time scales roughly coincide with scientific disciplines and levels of governance. The system transformation calls for overcoming manmade limitations in scientific disciplines and multi-levelled governance. The current fragmentation of research has been mapped, and member state-based JPIs are developing and aligning transnational research agendas on issues such as nutrition and health (JPI-HDHL) and food production (JPI-FACCE). The Food2030 Conference has emphasised the need for an integrative food and health systems approach and the strategic agenda of ESFRI has identified the need for a European health and food research infrastructure.

A food and health research infrastructure (RI) would facilitate breakthrough research and innovations that would enable a societal transition. It would provide services to the scientific community by aligning the data, tools and models for interdisciplinary and public-private research collaboration along the food chain. For example, such an RI would facilitate linkage, pooling and standardisation of data from nutrition cohorts and surveillance, including consumer-generated data on matters such as food purchase, recipes, preparation and consumption. It would innovate dietary assessment for etiologic research and pan-European surveillance – that is, harmonise and standardise food composition tables at the EU level, and expand these with indicators of environmental sustainability, accessibility in the food environment, prices & affordability and preferability based on things like sensory characteristics. It would foster innovation in products and technologies towards a more sustainable food supply chain and the evaluation of products for effects on consumer health and well-being. It would facilitate research on the determinants of dietary behaviours and physical activity via apps, sensors and wearables, linking behaviour to the food environment, supermarkets and food outlets. It could be positioned as an independent RI, curating data from public & private partners and securing the privacy of data owned by consumers or the private sector. Framed this way, a European food, nutrition and health RI would attract young and innovative researchers, and promote the breakthroughs needed to make the current food system sustainable, healthy, socially inclusive and economically competitive for the 21st century.

To establish, consolidate and advance knowledge on diet, nutrition and public health, there is a need for standardised cohort and intervention data, as well as nutrition surveillance. This data includes the determinants of diet & physical activity, the intake of food & nutrients, the status & function of the body and relations to health & risk of disease. Standardisation, harmonisation and modelling of data will allow them to be linked, enabling realistic scenarios and projections of alternative mitigation strategies across Europe. To address environmental sustainability, the interrelatedness of agricultural commodities, food processing and food composition databases is equally essential. Indicators of sustainability, food safety, sourcing, prices, sensory information, etc. need to be incorporated within food databases to allow for multiple functionalities in the food system. To ensure that public health strategies are effective, the mechanisms that underpins their anticipated impact on population health needs to be corroborated in experimental and biomedical research in molecular, physiological, psychosocial, neurocognitive and similar disciplines. To strengthen public health practice, evidence on effectiveness of intervention programmes & best practices need to become easily accessible to public health professionals. Taken together, this creates a need for a data infrastructure that would connect data from surveys, epidemiological research, clinical experiments and laboratory & experimental facilities. Such a network could facilitate breakthrough research that jointly addresses diet, physical activity and their determinants, and which allows linkage of dietary habits to their causal relations with public health, environmental sustainability and social inclusiveness.

Both nutritional health and environmental sustainability of diets must be taken into account when developing sustainable food-based dietary guidelines and personal dietary advice. Foresight studies and quantitative agricultural and public health models are required to compare the health and sustainability outcomes of such guidelines in relation to the underlying food chains. This will help promote the most effective innovations to reduce the environmental burden in agriculture, food technology and product development. Compared to current practice, this will require in-depth analysis of commodities and food groups at an advanced level, addressing energy, water and other resources used in production and transport as well as potential needs for nutritional enrichment. Food industries, retail and public health will all ultimately benefit from insight into the accessibility and affordability of dietary patterns to vulnerable population groups, in poor food environments and competitive market segments.

To ensure social and economic inclusiveness, specific attention must be given to socio-economic determinants of diet and lifestyle, including mitigation strategies via subsidies and taxes, information and ICT-based feedback mechanisms. Socio-psychological studies and sensory & cognitive research on food preparation & eating behaviour, situational determinants and the direct rewards of eating are required to facilitate the change in diets and lifestyle habits. There needs to be specific attention for the innovation potential of citizen science, including

integration of consumer-generated data, meta-data and sales data from private companies. It must become clear how food products and meal composition can help reduce meat consumption, which nutrients may increase risks, whether enrichment is required, what is acceptable, and what the preferred methods for food storage and preparations practices are.

To advance standardisation, facilitate data exchange, and improve the efficiency of data collection, it is crucial to improve the assessment of dietary exposure through emerging ICT developments. This must go hand in hand with assessing consumer behaviour via personal monitoring technologies. In addition to public data, much relevant data and information on foods, food technology and consumer profiles are owned by private companies and retail. Basically, private & retail companies and public health agencies require similar data infrastructures to assess needs and obtain an insight into market segments and preventive policies. Data linkage and research can achieve a level of detail that identifies specific urban areas and consumer groups. Governance practices need to be developed to unlock the potential of this data and use it by consumers and public & private parties. To safeguard privacy and ethical issues, the data could be curated by transparent mechanisms run by independent public bodies. A requirement for such a development is that consumers can make their data and information available for scientific research, as a form of citizen science, on a voluntary basis that respects their personal privacy. In return, they could benefit from high quality feedback on their diet and lifestyle and/or local policies improving their food environment.

In summary, there are numerous scientific challenges for developing and implementing effective strategies to transform the European food system. Interdisciplinary & in-depth research, data linkage & exchange, and public-private collaboration are required to generate the required knowledge and co-create effective mitigation strategies at all levels of governance. A connective research infrastructure in the domain of food, nutrition and health must be developed to enable the research community to tackle the societal challenges and work toward a healthy and sustainable food system.

About the authors

Louise O. Fresco (1952) is president of the executive board of Wageningen University & Research, one of the world's leading centres in agriculture, food and environment. Before this position, she served as university professor at the University of Amsterdam (UvA) and, earlier still, held a chair in Wageningen, as well as several guest professorships in other countries. Fresco worked at the UN Food and Agriculture Organization (FAO) in Rome for more than nine years, first as director of research, then as assistant director-general. She is a member of six scientific academies and has published over 160 scientific articles and policy papers, as well as eight non-scientific books in Dutch. Fresco has published widely outside her scientific field as a columnist, literary critic and a writer of novels and essays (in Dutch), and is an acclaimed public speaker. She served on the boards of the Rabobank and Unilever, as well as several national and international public institutions. Her latest book is Hamburgers in Paradise (Princeton). Fresco has received several awards for her contributions to food and agriculture.

Krijn Poppe (1955) works as senior economist at Wageningen University & Research, currently in a position as research manager at Wageningen Economic Research. He provides scientific support to decision makers in policy and business that helps them understand and act upon trends in the agri-food sector. Poppe is involved in a number of research projects for the European Union on the European food industry, ICT and research infrastructures for food & health and the farm accountancy data network. For several years he co-led SCAR's strategic working group AKIS. Poppe spends one day a week working as a member of the Council for the Environment and Infrastructure, which advises the Dutch government and is active in a number of voluntary management positions in the profession and in agriculture.

Pieter van 't Veer (1957) is a nutritional epidemiologist and holds the endowed Wageningen University & Research chair on Nutrition, Public Health and Sustainability at the Division of Human Nutrition. From 2002 to 2015 he chaired the Nutrition and Epidemiology group at Wageningen University. Van 't Veer previously worked for the Dutch Cancer Society, the TNO Nutrition Institute and the chair group Epidemiology and Public Health at Wageningen University. His scientific career initially focused on diet and carcinogenesis and gradually shifted to NCDs, biomarkers, exposure assessment, dietary habits & prevention and, finally, environmental sustainability & food systems. He supervised projects on diet and breast cancer & GI-tract cancers and was involved in EU-funded projects on cardiovascular disease (EURAMIC), dietary assessment for pan-EU surveillance (EFCOVAL), harmonising dietary requirements (EURRECA), and national programmes to advance community health (AGORA). To advance transdisciplinary multi-stakeholder research, Van 't Veer is actively involved in the EU-funded projects EuroDISH and RICHFIELDS, which aim to establish a food, nutrition and health research infrastructure for Europe. His contributions to the present document were funded by the Global One Health programme of Wageningen University & Research.

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