JPI

a healthy diet
for a healthy life

STRATEGIC RESEARCH AGENDA

February 2019 (3rd edition)

Joint Programming Initiative "A Healthy Diet for a Healthy Life"

Foreword

We are proud to present the third edition of the Strategic Research Agenda (SRA) of the Joint Programming Initiative 'A Healthy Diet for a Healthy Life' (JPI HDHL). The JPI and this document are intended to establish greater integration of research in the fields of food, nutrition, health and physical activity, and increase the impact of scientific efforts within the European Research Area.

The SRA is built on the same overarching principles as the previous version (2015): it provides a framework for coordinated and structured research activities in order to achieve tangible societal and health impact. In the current edition we have moved, however, from the traditional research pillar to a model with three research areas:

1. Citizens, Diet and Behaviour
2. Food for Health
3. Diet, Health and Disease

We expect this new approach will even further facilitate integration of research within the domain of food, nutrition, health and physical activity.

Tenth anniversary

In 2008 the first steps towards the foundation of the JPI's were made, and the JPI HDHL was established at the end of 2009. New partners from different backgrounds, who were not used to working together, had to learn to speak the same language and to create an atmosphere of mutual trust and understanding before they could start working towards their shared ambitions.

Once it was up and running, the collaboration turned out to be very productive. Since the JPI HDHL started the partners have agreed a common vision and developed an SRA - updated on a regular basis - and also delivered two implementation plans, which have resulted in over 15 joint actions - mostly carried out without financial support from the European Commission (EC). The partners used a variety of innovative instruments in order to get as much impact as possible from Research and Innovation investments addressing societal challenge, such as knowledge hubs and data-sharing technology, but also training sessions and joint calls.

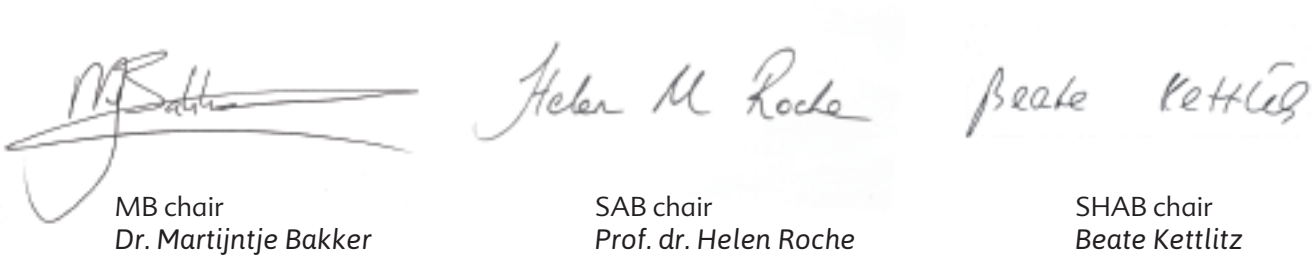
The work and achievements of the JPI HDHL are of great interest to society, academia and industry. Its website, for instance, has over 30,000 unique visitors a year from around the world, and several countries are interested in joining the initiative.

Twenty-three of the twenty-six member countries have participated in at least one Joint Action; 14 of them partnered in three or more funding activities. Overall, the 11 Joint Actions delivered four Knowledge Hubs and 38 research projects, involving over 200 research institutes in Europe and beyond, [see Annex I] with a total budget of over 85 million.

Valuable insights

The research projects, initiated via the first Joint Actions, have already delivered valuable new insights in the field of assessment of food choice drivers, food intake and the health effects of food products. For example, The Determinants of Diet and Physical Activity Knowledge Hub (DEDIPAC), a multidisciplinary consortium of over 300 scientists from 68 research centres in 13 countries across Europe, has created an online toolbox which summarizes the quality of assessment methods for diet, physical activity, and sedentary behaviours, and produced a detailed roadmap of the first steps towards cross-European surveillance.

We believe this updated SRA will lead the way for our member countries to further integrate research on food, nutrition, health and physical activity. The intention is to facilitate the translation of new research insights into policies and more-effective health interventions.



MB chair
Dr. Martijntje Bakker

SAB chair
Prof. dr. Helen Roche

SHAB chair
Beate Kettlitz

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Summary JPI HDHL SRA

Around the world, countries are struggling with an alarming rise in lifestyle-related diseases, with continuing increases in incidences of obesity, cardiovascular diseases, diabetes, cancer and chronic respiratory illnesses, with huge societal and economic consequences. All these conditions are associated with poor dietary quality and insufficient levels of physical activity. At the same time, societies are facing an ageing population with high age-related prevalence of chronic disease, with an increasing number of elderly being either underweight or overweight, with associated micronutrient deficiencies. The battle against unhealthy lifestyles is interconnected with other societal challenges. From the JPI HDHL perspective, the effect of food production and consumption on biodiversity and climate change, and vice versa, is a particular concern. A mind-shift is needed wherein the focus is on dietary patterns and lifestyles that are both healthy and sustainable.

To tackle these challenges research and innovation are crucial, as there are still significant knowledge gaps that prevent society from doing so. In the JPI HDHL, 26 countries from within and outside of Europe are working on a programmed approach to align national R&I strategies in the field of food, nutrition and health, and also on funding new research. The JPI HDHL SRA provides a framework for coordinated and structured research activities in order to achieve tangible societal impact. In this new version, the traditional research pillars have been changed into a model with three research areas, which have been designed to further facilitate the integration of research in the domain.

The three new areas are listed below. Interconnectivity between these areas is an important strategic objective of JPI HDHL, and opportunities for this have been highlighted in the SRA.

1. **Citizens, diet and behaviour:**
   Measuring, monitoring and changing dietary and physical activity behaviour
   - Measurement and understanding; the themes of nutritional and physical activity biomarkers, standardization, prediction of behaviour and analysis of social inequality.
   - Policies to change behaviour; policy intervention programs and implementation strategies.

2. **Food for health:**
   Providing safe and nutritious food products for a healthier and sustainable diet, working towards a secure future food-system
   - Safe and sustainable food for a healthy diet; bioactives, food safety and product reformulation.
   - Understanding nutrient utilization and metabolism; bioavailability and the effects of food processing.
   - Food production for precision nutrition health; personalized nutrition and food safety.

3. **Diet, health and disease:**
   Targeting the mechanisms that prevent lifestyle-related disease and promote health
   - Malnutrition and related diseases; the identification of underlying mechanisms, precision nutriton concepts and overweight and obesity prevention and treatment.
   - Physiology of food behaviour; the regulation of food intake and the gut-brain axis.
   - Adverse reactions to food; including food allergies and food intolerances.

Besides the research areas and their topics, the JPI HDHL aims to contribute through its work to a number of overarching themes, that are essential for delivering real societal impact. Among others, these are FAIR data principles, Research Infrastructures and sound evaluation and monitoring. The SRA also provides a framework to improve integration and synergies between relevant networks and initiatives. And, finally, efficient communication and dissemination of our activities, results and implementation strategies is paramount to achieving the JPI HDHL objectives.

Introduction

Tackling the rise of chronic disease through healthier and sustainable diets

Around the world, countries are struggling with an alarming rise in lifestyle-related diseases, with continuing increases in incidences of obesity, cardiovascular diseases, diabetes, cancer and chronic respiratory illnesses, with huge societal and economic consequences. Key risks involved are overweight and obesity, high blood pressure, insulin resistance, hyperglycaemia and hyperlipidaemia. All these risks are associated with poor dietary quality and insufficient levels of physical activity. The promotion of lifestyles with healthier diets and appropriate levels of physical activity is, therefore, of utmost importance for the prevention of these conditions in Europe and beyond.
Globally, an increasing number of people consume an unhealthy and unbalanced diet while, in Europe, only one in two adults has sufficient levels of physical activity[1] . To date, no country has been able to effectively reverse this trend. At the same time, societies are facing an ageing population with high age-related prevalence of chronic disease, with an increasing number of elderly being either underweight or overweight, with associated micronutrient deficiencies.

The health gap between people from higher and lower socioeconomic classes is widening. The first group often has the knowledge, motivation and financial means to make healthier, more-sustainable choices. People from the second group tend to have less-healthy dietary patterns and lifestyles, which negatively impacts their health status. This leads to shorter lives, and fewer years experienced as healthy, compared to people with a higher socioeconomic background.

Impact of lifestyle-related diseases

While the global burden of many diseases has decreased over recent decades, the number of years lost (per person) to lifestyle-related diseases such as diabetes has increased[2] . In Europe, lifestyle-related diseases are responsible for 80% of deaths and 77% of diseases. It is estimated that about 26% of those deaths are premature, meaning that people died before they reached the age of 70[3] . The associated, global costs of overweight and obesity are $2.0 trillion per year[4] — taking into account direct and indirect costs, such as associated health care costs, loss of labour productivity and quality of life. In Europe about 50% of citizens are overweight and over 20% are obese[1].

Food and nutrition security

The World Health Organization (WHO) speaks of the *double burden* of malnutrition - characterized by the coexistence of undernutrition (stunting, wasting, vitamin and mineral deficiency) along with overweight, obesity or lifestyle-related diseases - within individuals, households and populations, and across the life-span. The societal and economic impact of the double burden of malnutrition is serious and lasting, with low and middle-income groups bearing the greatest burden. The double burden of malnutrition shares both drivers and solutions and, therefore, requires integrated actions.

> ***"Nearly 800 million people remain chronically undernourished and 159 million children under five years of age are stunted. Approximately 50 million children under 5 years are wasted, over two billion people suffer from micronutrient deficiencies and 1.9 billion people are affected by overweight, of which over 600 million are obese. The prevalence of overweight and obesity is increasing in nearly all countries"[5]***

The battle against unhealthy lifestyles is interconnected with other societal challenges. From the JPI HDHL perspective, the effect of food production and consumption on biodiversity and climate

change, and vice versa, is a particular concern. According to the European Academies Science Advisory Council *"the desired outcome of food and nutrition security is access for all to a healthy, affordable and environmentally-sustainable diet"*[6] . Healthy and environmentally- sustainable food are not the same concept. Europe needs a mind-shift wherein the focus is on dietary patterns and lifestyles that are both healthy and sustainable.

Connection to global and European policy developments

Sustainable Development Goals and the Rome Declaration on Nutrition

Since the foundation of JPI HDHL, the political commitment to battle unhealthy lifestyles and achieve food and nutrition security has grown significantly. In 2016 the United Nations' agenda ***Transforming Our World: the 2030 Agenda for Sustainable Development*** was published, containing 17 Sustainable Development Goals (see figure 1)[7]. The governments of the 193 countries who adopted the agenda have agreed to work towards comprehensive, integrated and universal transformations.

Six of the 17 **Sustainable Development** Goals, detailed in the UN agenda, are directly related to nutrition, diet and health:

Figure 1: UN Sustainable Development Goals

GOAL 2: End hunger, establish food security, improve nutrition and promote sustainable agriculture.

GOAL 3: Ensure healthy lives and promote well-being for all throughout the life span.

GOAL 10: Reduce income inequality within and between countries.

GOAL 12: Ensure sustainable consumption and production patterns.

GOAL 14: Conserve and sustainably use our oceans, seas and marine resources.

GOAL 15: Protect, restore and promote **sustainable use of terrestrial ecosystems.**

Links to lifestyle-related societal challenges are embedded within many of the 17 Sustainable Development Goals. Ban Ki-moon, UN Secretary-General, phrased the key role of nutrition in the following way:

> ***"Nutrition is both a maker and a marker of development. Improved nutrition is the platform for progress in health, education, employment, empowerment of women and the reduction of poverty and inequality, and can lay the foundation for peaceful, secure and stable societies."*** [8]

In parallel with the establishment of the Sustainable Development Goals, the Food and Agriculture Organization (FAO) and WHO member countries have worked towards the Rome Declaration on Nutrition and the accompanying Framework for Action. This agreement, first endorsed by 170 countries and adopted in 2016 by the United Nations General Assembly via the *"UN Decade of Action on Nutrition"*, aims to stimulate increased action worldwide to end global hunger and malnutrition, and ensure access to healthier and more sustainable diets.

Governments are invited to set national nutrition targets for 2025 and milestones towards these targets, based on the agreed indicators. The United Nations has determined that the FAO and WHO will lead implementation of the *"Decade of Action on Nutrition"*. The Framework for Action commits governments to exercise their primary role and responsibility for eradicating malnutrition. This includes addressing under- and overnutrition, nutrition lacking specific, essential micronutrients, and reducing the burden of lifestyle-related diseases across all age groups.

Physical activity

Increasing physical activity, coincident with reducing sedentary behaviour, will also contribute to achieving the Sustainable Development Goals, as outlined in the Bangkok Charter[9] . In addition to the multiple documented health benefits of physical activity, societies that are more physically active also perform better on achieving other goals of the United Nations Sustainable Development Agenda 2030 than those directly related to health. Lack of awareness and investment has led to slow global progress in increasing physical activity. Worldwide, 1 in 4 adults and 3 in 4 adolescents (11—17 years-of-age) do not meet the global recommendations for physical activity set by the WHO. As countries develop economically, populations become less active and more sedentary, sometimes very dramatically, due to factors such as changes in transportation patterns, increased use of technology, and urbanization. In 2013, the estimated global cost of physical inactivity was INT$54 billion* per year in direct health care, with an additional INT$14 billion attributable to lost productivity. This accounts for 1—3% of global national health care costs, excluding costs associated with mental health and musculoskeletal conditions[10].

Food-systems approach

The European Commission calls for an integrated food-systems approach, in which multi-sectoral policy and governance, to enhance the production and development of healthier and more-sustainable products, goes hand in hand with multidisciplinary approaches to improve healthy and sustainable consumer behaviour[11].
Food systems encompass the processes and infrastructures needed to feed a population: growing, harvesting, processing, packaging, transporting, marketing, consumption, and disposal of food and food-related items. As stated in the European Research and Innovation for Food and Nutrition Security Policy Framework[11], food systems should ensure food and nutrition security by providing safe and nutritious food for healthy and sustainable diets.
Research and innovation are crucial in enabling a transition to sustainable food systems, as underlined in the European Commission's FOOD2030 staff working document . Such a transition

* An international dollar would buy in the cited country a comparable amount of goods and services a U.S. dollar would buy in the United States.

requires multidisciplinary and integrated approaches, engaging with stakeholders and the general public, and improving the impact of research and innovation investments.
In the European context, the FOOD2030 policy framework defines four priorities:

- Nutrition for sustainable and healthy diets
- Climate-smart and environmentally-sustainable food systems
- Circularity and resource efficiency of food systems
- Innovation and empowerment of communities, with closer partnerships with industry and food producers, and development and implementation of relevant Food and Nutrition Security policies at all geographical scales.

Food 2030 expert group

The independent Food2030 expert group proposes to break down the challenge of climate-smart, sustainable food systems for a healthy Europe into three missions. One of them is to **"Improve dietary patterns and lifestyles to achieve a 50% reduction in the incidence of lifestyle-related diseases in 2030, while reducing the environmental impact of food consumption"**[12] .

The group identifies five focus areas for this challenge:

1. **Stop Obesity,**
2. **Healthy ageing,**
3. **Healthy and sustainable diets,**
4. **Improve food processing, and**
5. **Personalized nutrition.**

The expert group explicitly recommends the various actors to take responsibility and "*develop a unified, health-centric, climate-smart, sustainable and resilient food system for Europe, based on research and innovation, that works according to a systems approach and with substantially higher investment compared to the current allocation from the EU and other budgets*". The expert group recommended that EU Member States align their national (and regional) research and innovation programmes with the societal challenges and missions described.

The importance of research and innovation

Nutrition sciences involves many stakeholders in government, society and industry, connecting with a wide range of disciplines. These include agriculture, aquaculture, fisheries, food processing, toxicology, behavioural, economic and environmental sciences, IT, health, wellbeing and medicine. New insights into nutrition, health and lifestyle boost progress in these areas and vice versa. A key example is the importance of a sustainable and healthy diet in supporting (or perhaps even replacing) treatment of people with chronic diseases.

Research has substantially increased our understanding of how dietary and individual components are linked with health and disease. This has enabled governments, health agencies, communities and individuals to take well-considered actions to establish healthier and more-sustainable diets and to reduce the risk of early onset of lifestyle-related disease. Examples include the reduction of trans fatty-acid levels in food products and recommendations to limit the consumption of soft drinks and fruit juice. But there are many other effects in relation to diet and health that require elucidation. Some issues, such as synergies between certain food components and physical activity, and variable health impacts within different population sub-groups, are ripe for investigation.
The introduction of food labelling has increased health awareness among consumers, whereas recent insights into food in specific environments — such as soft drinks and unhealthy snacks at school, the manner in which confectionary is displayed in supermarkets, and advertising directed at children — and their impact on health behaviour have led to interventions by policymakers, industry and retail.

Knowledge gaps

Despite extensive research progress over many years, there are still crucial gaps in our knowledge. Filling these gaps will support policymakers to tackle societal challenges in food, nutrition and health.

There is a need:

- to better understand how the interplay of biological, psychological, environmental, economic and social factors affects a healthier, more sustainable lifestyle
- for enhanced insight into the relationship between lifestyle and disease. For example the relationship between dietary components and different chronic diseases such as cardiovascular disease, diabetes and obesity-related cancers
- to understand how to permanently influence citizens' and consumers' health behaviours; research has shown that individual interventions, such as education around healthy and sustainable food, are not enough to improve or maintain desired behaviours
- to develop and validate reliable models that enable prediction of the long-term biological effects on human health of bioactives from, for example, (so-called) superfoods and functional foods
- to understand variability between people with respect to sensitivity to poor diets and lack of physical activity, and to healthy diets and physical activity, thereby building a more comprehensive and evidence-based understanding of personalized nutrition and health
- to develop methods that support multidisciplinary research actions, in order to fill the knowledge gaps detailed above

Collaboration with government

Research and innovation efforts, to fill these knowledge gaps, should work more in conjunction with regulatory and governance actions than at present. This would feed into both the health and sustainability aspects of dietary guidelines, and address behavioural interventions in a more holistic way. It would also establish a tight connection between new learning needed for food safety regulation while boosting the development of novel foods.

The Joint Programming Initiative 'A Healthy Diet for a Healthy Life'

Joint Programming. Why? Who? How?

Why?

Joint programming initiatives are country-driven and focus on the knowledge needed to tackle societal challenges that no country can solve alone. The research area that focuses on the links between nutrition and health, as well as nutrition-related public health interventions, often falls into the gap between the agricultural and health domains. This leads to underinvestment, according to a recent mapping of the Research and Innovation investment of 11 countries by the Strategic Working Group on Food Systems of the Standing Committee of Agricultural Research[13]. An analysis of existing policies and strategies, of more than 20 countries, mentioned in the same report, showed an underrepresentation of food innovation, nutrition and health in comparison to agriculture, food production and food safety. The same underinvestment is highlighted by the independent Food2030 expert group in relation to funding for the European Horizon 2020 research program[13]. These, very recent, findings underline the importance of strengthening national research investments through a programmed approach.

Vision

The vision of the JPI HDHL is that **by 2030 all citizens will have the motivation, ability and opportunity to consume a healthy diet from a variety of foods, have healthy levels of physical activity and that the incidence of diet-related diseases will have decreased significantly.**

A programmed approach, with trans-disciplinary expertise, knowledge, facilities and approaches, ranging from basic research to large population studies and controlled trials, is needed to truly understand the relationship between diet, physical activity and health. Research should cover a wide range of topics, from the influence of (epi)genetic differences on disease susceptibility and morbidity, to the factors affecting health-related and environmentally-sustainable behaviours. Implementation should take place at the regional and country level, at the multilateral level through JPI HDHL joint actions, and through the European Commission's Research and Innovation framework programme (Currently this is H2020; it will be succeeded by Horizon Europe on January 1st 2021).

Who?

As of the time of writing, the Joint Programming Initiative 'A Healthy Diet for a Healthy Life' (JPI HDHL), consists of 26 member countries** within and outside Europe. Together, they are working on the integration of research in the areas of food, nutrition, health and physical activity, to help prevent or minimize lifestyle-related chronic diseases. Their governments are collaborating voluntarily to increase the impact of their research investment, minimise duplication of research effort within Europe, and to collectively enhance the insights needed to enable the transformation into a healthier, more sustainable society. We invite countries able to demonstrate their willingness to invest in research and innovation, via transnational collaboration, to join this initiative.

How?

The JPI HDHL has the strategic goal to improve dietary quality in an environmentally-sustainable way, based on insights and developments in food, nutrition and the social and health sciences, and to develop evidence-based recommendations and innovative formats for food products. Together with changes in physical activity/sedentary behaviour this should have a major impact on public health, increasing quality of life and prolonging productive life, simultaneously reducing the environmental burden of diet.

The JPI HDHL is developing its programmed approach by:

- Stimulating **national alignment and inter-ministerial exchange** on the national level through exchange between the JPI Member Countries; developing supporting materials to help put the topic of Research and Innovation in food, nutrition and health on the national agenda; and active participation in member-state driven initiatives at the European level.
- **Supporting research excellence by funding regular** transnational competitive calls for proposals, and for knowledge hubs and other networks in the three areas defined in its Strategic Research Agenda (SRA).
- Supporting **development** of the needed **food, nutrition and health research infrastructure** by investment to fill identified knowledge gaps. The aim is to move towards activities such as the standardisation of methodology and terminology in the different scientific disciplines involved.
- **Investing in policy-science and stakeholder-science dialogues** by capacity building, through networking events and by implementing these principles in our own procedures. For example, stakeholder involvement at the level of strategic programming, communications and defining criteria for calls for proposals.

** Austria, Belgium, Canada, Cyprus (observer), Czech Republic, Denmark, Estonia (observer), Finland, France, Germany, Ireland, Israel, Italy, Latvia, Netherlands, New Zealand, Norway, Poland, Romania, Slovenia (observer), Slovakia, Spain, Sweden, Switzerland, Turkey, UK.

- **Communicating and disseminating scientific results from joint actions, as well as scientific needs** through scoping workshops, strategic workshops, intergovernmental workshops, projects workshops, mid-term and final symposia of funded projects, and the international JPI HDHL conference every second year.

The highest body of the JPI is the Management Board, on which representatives from national governmental bodies, such as ministries of health, agriculture and research, and science councils have seats. The Management Board is supported by the Scientific and a Stakeholder Advisory Board. See annex 3 for the governance structure. The global dimension of JPI HDHL is strengthened through its connection with global political commitments set by the United Nations (Sustainable Development Goals) and WHO/FAO (Rome Declaration on Nutrition) and by working in collaboration with research funders to globally tackle this pressing societal challenge.

Strategic Research Agenda

This SRA provides a framework for coordinated and structured research activities in order to achieve tangible societal impact. It offers individual member countries a solid basis for goals, objectives and strategies.

Though written from the perspective of its members, the SRA can also inspire governments, non-governmental organizations and industries, around the world, to align their research and policy-making activities. In its Implementation Plan the JPI HDHL describes the ambitioned funding and non funding activities for a set period of 2 — 3 years. See annex 4.

Area model

In the 2015 edition of the SRA, the determinants of diet and physical activity were combined into one research pillar. However, in the current agenda, nutrition and physical activity are at the centre of the research direction, spanned by three interconnecting and interacting areas (see figure 2):

1. **Citizens, Diet and Behaviour**
   Measuring, monitoring and changing dietary and physical activity behaviour
2. **Food for Health**
   Providing safe and nutritious food products for a healthier and sustainable diet, that will contribute to secure a future-proof food system
3. **Diet, Health and Disease**
   Targeting the mechanisms to promote health and help reduce lifestyle-related diseases

AREA 1:
Citizens, Diet and Behaviour, highlights the citizen role from the perspectives of both health and consumer.

AREA 2:
Food for Health strives to push primary food production, food processing and technological innovations towards increased availability of healthier and more sustainable food products.

AREA 3:
Diet, Health and Disease focuses on the questions if, when and how enhanced dietary quality, together with physical activity, can promote or maintain health for a longer time by reducing disease risk and/or reversing modifiable risk factors of common lifestyle-related diseases.

STRUCTURE: ONE COMMUNITY, THREE AREAS

KNOWLEDGE
links between three areas & challenges

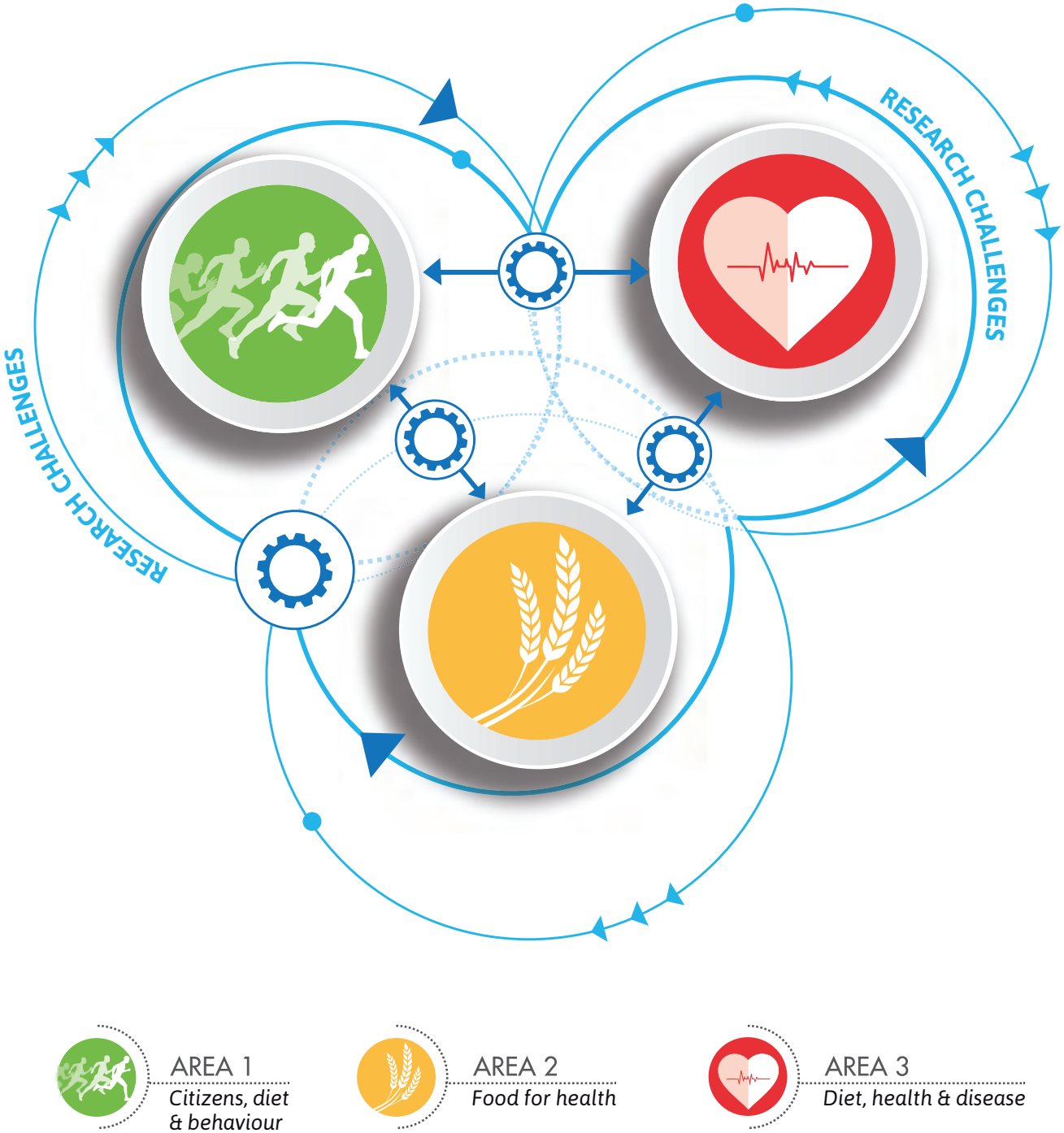


Figure 2: New schematic model of the research areas of the JPI HDHL. This new model aims to increase the inter-connectivity and relationships between areas that traditionally stand alone, thus facilitating trans-disciplinary approaches to solve research challenges within the remit of JPI HDHL.

Interconnectivity of the research areas

Interconnectivity, between traditionally distinct research areas, is an important strategic objective of JPI HDHL. **Bi-directional integration of knowledge and research capability** between the **three research areas** will advance the capacity and impact of the research initiated via JPI HDHL.
For example, a greater understanding of the health behaviour of people within countries and in different socio-economic classes, will improve our understanding of how to optimize interventions that enhance long-term healthy-nutrition behaviour and physical activity (Area 1 ***Citizens, Diet and Behaviour***). It will also highlight gaps in the production and processing of healthier food (Area 2: ***Food for Health***). Furthermore, exchange of knowledge and research results, from these areas, into Area 3 (***Diet, Health and Disease***) is vital, in order to maximize translation of research findings into applicable outcomes which help to maintain or optimise the health status of our citizens. For example, nutrition and health-research tools from the **Diet, Health and Disease** area - advanced biomarkers for the assessment of health effects, for example - must be made widely available to the technology and food processing sectors in the **Food for Health** area. This will ensure that research and industry can use state-of-the-art platforms to assess the efficacy of novel food products or improve existing foods in a goal-oriented way. Likewise, leads for new or improved interventions generated by Area 3 need to be examined in Area 1 for long-term effectivity.

Alignment and Synergy with other missions/challenges

JPI HDHL already has a synergetic connection with JPI FACCE (in Agriculture, Food Security and Climate Change), JPI OCEANS (Healthy and Productive Oceans) and several European Research Area Networks (ERA-NETs), such as SusCrop, SusAn and SusFood, that mainly focus on primary food production.
JPI HDHL will further strengthen its trans-disciplinary dialogues to better understand the collective impact of economic and environmental factors on the production levels and market prices of health-promoting foods including fruit, vegetables and seafood. This aim will require close collaboration with other stakeholders and initiatives, in particular JPI FACCE and JPI OCEANS. The current JPI HDHL Implementation Plan provides further details about concrete collaboration efforts.

Area 1
Citizens, Diet and Behaviour

Measuring, monitoring and changing dietary and physical activity behaviour

Background

According to the JPI HDHL vision ***"by 2030 all citizens will have the motivation, ability and opportunity to consume a healthy diet from a variety of foods, have healthy levels of physical activity, and the incidence of diet-related diseases will have decreased significantly"***. This requires citizens to shift towards more active lifestyles and healthier diets, in a sustainable way.

In order to meet the ambitions of JPI HDHL, we need to better understand the interplay of biological, psychological, environmental, economic and social factors. Moreover, it is vital to understand citizens' health behaviour and how to influence it[14-15-16]. These insights will help policymakers and health professionals develop interventions that truly improve diet and physical activity and thereby public health.

Current state of play

Behavioural science has much to contribute to our understanding of health-related behavioural change. However, although interventions to promote behaviour change frequently show some promise, they often fall short of expected reach and impact[17].

Poor reasoning, and non-scientific approaches to intervention development and evaluation used by governments and health policymakers, reduce the likelihood of these interventions being effective. In addition, observing behavioural change, abstracted from the contexts within which the behaviour occurs, is likely to lead to failed interventions. Most interventions target health education, knowledge and rational thought processes. These may result in some successes in behavioural change. However, their effect is likely to be limited, as these target only one part of the way human beings function. Human behaviour is also governed by an automatic system that responds to environmental and social cues, in ways that require minimal conscious engagement.

Traditionally, attempts at behavioural change regarding eating and exercise, are focused on the individual. However, an enabling environment is also important. The food chain, including retail, the spatial environment and the social and digital environment are all aspects which need to be considered. In particular, interactions between the individual behavioural determinants and the environment affect healthy diets and healthy levels of physical activity. Not only unhealthy diets, but also low levels of physical activity have been associated with an increased risk of obesity, diabetes and cardiovascular diseases[18-19] . In addition, the negative health effects of sedentary behaviours such as working behind a desk or watching television for many hours - which are independent of overall physical activity levels - are increasingly recognized as risk factors. Furthermore, the overall composition of a person's day, such as how sedentary, how much sleep, amount of dark and light, duration of moderate versus vigorous activities have a combined, rather than an independent, impact upon health[20]. These insights suggest a need to focus interventions not only on more physical activity but also on specific strategies to replace or reduce sedentary time. For example via the concept of 'mini breaks' that replace some seated time with light or moderate activity.

The systematic and consistent measurement of physical activity and diet across the EU would be a valuable basis for other work in this research area (e.g. informing policy, examining social economic differences, changing behaviour and understanding impact on health). Dietary assessment has, so far, been mostly based on self-reports. However, these are often inaccurate, casting doubt on the results, for example, of nutritional epidemiology and observational studies on diet and health. Eating patterns are getting more complex, with people eating out or on-the-go more often. Hence identification of foods, and portion-sizes consumed, is increasingly unreliable, from personal recollection or even from a dietary-intake record[21]. However, with the latest developments in metabolomics the use of food-intake biomarkers in dietary assessment is becoming within reach[22].

The dietary intake and physical-activity assessment research area will also benefit from recent

developments in IT, and sensor technology[23]. These rapidly emerging fields have provided a wide range of novel information sources, such as retail-scan data on food purchases and GPS-data, and mobile devices for non-invasive assessment of diet and physical activity[24]. These include photo-based dietary records, pedometers and heart-rate monitors. Application of new and emerging tools will allow the collection of more-objective data and better-differentiated insights into health-related behaviour. Mobile devices could also support citizens in maintaining healthy, sustainable behaviour, for example by translating scientific information into personalized messages that fit with and support their knowledge levels, physical needs and preferences[25].

WHAT HAS BEEN ACHIEVED SO FAR

THE DEDIPAC KNOWLEDGE HUB

What is DEDIPAC? The Determinants on Diet and Physical Activity (DEDIPAC) Knowledge Hub was a multidisciplinary consortium with over 300 scientists from 13 countries across Europe. The main objective was to understand the determinants of dietary, physical activity and sedentary behaviours and to translate this knowledge into more-effective promotion of a healthy diet and physical activity.

Activities: A comprehensive, scientific overview has been developed that explains nutrition and physical activity behaviours. In addition, DEDIPAC delivered a toolbox for the development, implementation and evaluation of interventions and policy measures to improve and support healthy lifestyles.

Added value of the JPI HDHL: Working on the harmonization and standardized collection of data in a transnational collaboration delivers much more impact. The variety of the data emerging from different countries contributes to a better understanding of the environmental factors affecting nutrition and physical activity behaviour. DEDIPAC has provided standardized methods, for evaluating and implementing interventions, that can be used in different countries.

THE FOODBALL CONSORTIUM

What is FOODBALL? The Food Biomarkers Alliance (FOODBALL) was a consortium of 22 partners from 11 countries. The project's goal was to develop strategies for food-biomarker discovery and validation, and to identify intake-biomarkers for a range of foods.

Activities: FOODBALL explored and/or validated a range of dietary biomarkers, for important foods that are relevant to public health in Europe. In addition, to aid harmonization of methodologies, FOODBALL developed new (and improved existing) platforms for sharing knowledge and resources within the scientific community.

Added value of the JPI HDHL: FOODBALL worked closely with the European Nutritional Phenotype Assessment and Data Sharing Initiative (ENPADASI), also funded by the JPI HDHL. FOODBALL also allowed European researchers' career progression within the international researchers arena.

Key topics and societal impact

The **Citizens, Diet and Behaviour** area will deliver insight into the current status quo of citizen behaviour. This will facilitate the development and implementation of evidence-based (behavioural) interventions and policies that enhance healthy, sustainable behaviours and that minimize existing inequalities across different socio-economic groups. Research generated in this area will provide guidance to policymakers, professionals in the public health area, the food industry and consumers, globally supporting citizens to maintain or improve their health.

The JPI HDHL consortium defined two key research topics for the **Citizens, Diet and Behaviour** area:

1. **Measurement and understanding:** the themes of nutritional and physical activity biomarkers, standardization, prediction of behaviour and analysis of social inequality.
2. **Policies to change behaviour:** policy intervention programs and implementation strategies.

1. Measurement and understanding

Biomarkers of food intake and physical activity

Sensitive and reliable biomarkers are vital in the assessment of diet and physical activity. There is a need for biomarkers to assess the intake of specific nutrients, food or food components. For example food metabolomics, which investigate the presence of food-derived metabolites in different human tissues after food consumption, could be improved to complement and/or validate more traditional dietary assessment methodologies, such as 24-hour recollection and food-intake records. In relation to physical activity, biomarkers and e-monitors have been implemented in professional sport to measure performance and training. In recent years scientific efforts have been focussed on developing a set of biomarkers and e-monitors for 'ordinary' physical activity and sports, in order to measure physical activity more objectively [26-27] .

Towards standardized monitoring

Standardized monitoring of health behaviours and their determinants allows scientists to link data from different studies and perform large-scale analyses of diet and physical activity. This approach makes it easier to demonstrate whether an intervention is effective or not, to evaluate and compare current policies and to develop new ones. The DEDIPAC Knowledge Hub, the first joint action funded by JPI HDHL, has provided initial guidance on harmonized assessment of diet, physical activity and sedentary behaviour across the life span in Europe, to be achieved by standardizing methodologies. These new tools have been applied in a limited number of studies within DEDIPAC. The next step is to further develop and validate (IT) tools and technologies to improve and standardize assessment, building on the outcomes of DEDIPAC and benefitting from the possibilities inherent in 'big data'.

Predicting and changing health-related behaviours

Additional understanding of the broad range of determinants of diet, food choice, physical activity and sedentary behaviour, and attaining/maintaining a healthy body is needed. For example, there exists scarce research and data on the impact of economic status on healthy diets and physical activity. A range of approaches (e.g. natural experiments, predictive studies, qualitative work or randomized, controlled trials) might be appropriate in studying different determinants and their interrelationships.

Analysis of social inequality

Data that quantify health inequalities and variations in health determinants across different socio-economic and minority groups are currently limited. Both health and health behaviours - including dietary habits and physical activity - are unequally distributed across different socio-economic

groups. But the causes and consequences are not well understood. Research should focus on the effects of interventions in different socio-economics groups, with particular attention to intersectionality*** in order to ensure that health gaps do not widen but, preferably, are reduced. This will allow the design of more-effective interventions.

2. Policies to change behaviour

Intervention programs

Mechanisms of behavioural change range from controlled to automatically-processed influences on behaviour and are still underexplored in the areas of nutrition and physical activity, especially when these combine. Understanding these mechanisms and their interactions could help elucidate where best to target intervention programs.

Longitudinal studies of interventions of sufficient intensity (both in the amount of interventions and the duration) to produce effects would be valuable. It is vital to identify the drivers of health-risk behaviours, in order to design effective health-promoting interventions and policies. In the beginning phase of intervention design, it is necessary to understand the full pathway from research evidence and policy to behavioural change and health impact. Interventions should be pragmatic and reflect 'real life' situations, helping to reduce the gap between science and society. Researchers need to work with local, regional and national implementation teams (e.g. service providers, intervention developers, funders and policymakers) to better understand and overcome the many obstacles to implementing evidence-based programs. The outcomes of such studies should be assessed with a standardized evaluation framework and shared in an open access database of effective and usable interventions that promote healthy diets and physical activity.

A greater understanding of **life course health-risk behaviours** and identifying potential causes/determinants such as poor diet, inactivity and sedentary behaviour, could be translated via policy into practice, accompanied by more-effective and better-targeted health promotion. This will effectively potentiate the health, economic and societal benefits of **health-enhancing behaviours**.

Research should focus on finding combined strategies that increase citizens' motivation, ability and opportunity to make healthy choices — whether that means improving diet, increasing physical activity or reducing sedentary behaviour. Such strategies can be individually targeted, but should also target physical and social environments. Interventions might include freely-accessible open air fitness centres, supermarket layouts designed to 'nudge' people towards healthier choices or social media platforms that motivate people to improve their health. Actively involving consumers rather than approaching them as 'passive recipients' could achieve greater impact. Citizens need to be active, conscious and motivated in order to change their behaviour, whether choosing a healthy diet or maintaining optimal levels of physical activity. Tailored intervention strategies, based on direct biofeedback and self-monitoring, would help them adopt this approach. In order to establish such strategies, novel IT applications should make use of scientific insights from citizen science, participatory research and education. Software applications, with personalized recommendations for healthier diet, targeted food intake and healthy activity levels, should be considered when future research directions are discussed. In case of individually targeted interventions such as software application, the effects of group dynamics such as peer pressure and body image stigmatization should be taken into account.

Implementation strategies

There is a need for research on the efficacy of implementation strategies and governance issues. Large-scale health-promotion interventions (national policies) are sometimes dismissed for having limited effect, sometimes because the general public does not accept them. The issue here, is that there is not enough data for a rigorous assessment of long-term effects, and current policies do not support studies which would gather such data. Research could address these gaps by setting up

*** The complex, cumulative way in which the effects of multiple forms of discrimination (such as racism, sexism, and classism) combine, overlap, or intersect especially in the experiences of marginalized individuals or groups

longitudinal studies in conjunction with different health intervention policies to capture and measure the longer-term effects of health intervention policies. Primary prevention is, ultimately, the key to global population health. These studies would ascertain if better education and deeper knowledge may result in improved health status in individuals and populations. This would allow better understanding of the potential benefits of food and health literacy programs.

With DEDIPAC and the Policy Evaluation Network (PEN), JPI HDHL has initiated two important Knowledge Hubs to facilitate implementation and evaluation of intervention and policies. Building on their work, best practice recommendations for new large-scale interventions and evidence-based policies need to be implemented, and evaluated with appropriate standardized measures, to ensure efficacy.

Interconnectivity

To **measure and understand** health-related behaviours, it is important to examine individuals and groups. Behaviours are driven by personal motivations as well as the context in which people buy, choose, prepare and consume food. Such as the availability of affordable healthy and tasty foods in supermarkets, or the effect of food marketing and advertising.
This links closely with Area 2: **Food for Health**, which focuses on the food system. Understanding better the drivers behind behavioural patterns and feeding this into the way and type of food products will be supportive in moving towards a healthy food system. Further systematic and consistent monitoring of physical activity, sedentary behaviour and diet will provide a strong data basis for interpreting the influence of different health-related behaviours on various health outcomes. This can guide the focus of the research in Area 3: **Diet, Health and Disease**. Detailed and reliable assessment, together with systematic monitoring of diet and physical activity are essential in terms of understanding them as key determinants of health. This will allow, for example, detailed investigation of differences in socioeconomic status, their impact on health and vice versa. These analyses will support the development of effective policies and intervention strategies that help citizens avoid lifestyle-related diseases.

Area 2
Food for Health

Providing safe and nutritious food products for a healthier and sustainable diet, working towards a secure future food-system

Background

Ensuring supply of sufficient safe, nutritious and high-quality raw (food) materials for direct consumption and food production, at an affordable price, is a growing challenge. A key component of a secure future food-system is a well-functioning, socially-acceptable and sustainable food value-chain with a focus on food products for a healthy diet and tailored food products[28]. In particular, individual variations in nutrition response need more attention in this context. To tackle this challenge, research is needed that results in a better and deeper understanding of how food is metabolized in the body and how nutrients are made available for absorption. This would help to create the knowledge base that precision nutrition requires. In addition to these technologies, an important prerequisite in facilitating citizens to have healthy, more-sustainable diets is the supply of sufficient and high-quality (raw) materials and bio-actives for food production, and appropriate technology for processing raw materials into healthy food products with a high nutritional value.

Cross challenges — diet as a leverage for healthy and sustainable food systems

Global food production is a major contributor to climate change and depletion of the earth's natural resources (Global Nutrition Report, 2017). The opposite also applies: climate change, pollution and scarcity of water affect food and nutrition security. The situation is further aggravated by the increasing demand for food by the growing world population, changing dietary patterns and a significant upscale in the volume of food wasted throughout the whole chain (farm and sea to fork). Food portfolios need to be adapted in order to facilitate a major shift towards more-sustainable use of raw materials in food products. An example is the replacement of animal protein with protein from terrestrial and aquatic plant origin, and the utilization of valuable nutrients from food processing side streams[29]. At the same time, product reformulation - reducing levels of salt, sugar, fat, and portion sizes - should help reverse the worldwide rise in lifestyle-related diseases such as obesity, diabetes and cardiovascular disease[30].

Current state of play

There is growing recognition that a sustainable diet, i.e. a mainly plant-based diet, is generally consistent with current dietary recommendations and guidelines[31]. In western countries, however, overconsumption is common, and many people have high intakes of meat and (ultra-)processed foods that are rich in salt, fat and sugar. Addressing the issue of currently unhealthy, unsustainable diets would benefit the health of individuals and the environment[32]. Changes in food processing could increase the bioavailability of nutrients from plant-based foods, facilitate the reduction of sugar, fat or salt content and, as such, play an important role in achieving these goals.

Nutrient release from food, during digestion in the gastrointestinal tract, is affected by a large number of factors. These include how well a person chews the food, to the (potential) fermentation of indigestible food components by the intestinal microbiota. Understanding these factors is a key to the optimization of *bioaccessibility* (the amount of a nutrient released during digestion) and *bioavailability* (the amount of a nutrient that is finally absorbed and utilized) of nutrients[33-34]. This knowledge would be valuable in the investigation of new food ingredients, for example from residual raw materials from our global fisheries. Aquatic bio-actives are currently unexplored and underutilized as a food source, and often wasted.

Traditionally, dietary recommendations have been targeted at the average population level. However, current research has shown that food product risks and benefits, as well as nutritional requirements, vary significantly between groups and individuals within populations, depending on, for example, age, gender, genetic make-up and disease states. In trials, about 40% of a target cohort usually respond to an intervention, meaning 60% do not[35]. A better understanding of the factors determining why one individual responds while another does not, is crucial for the development and production of food products with well-substantiated health effects.

WHAT HAS BEEN ACHIEVED SO FAR

the Knowledge Platform on Food, Diet, Intestinal Microbiomics and Human Health

What is the Knowledge Platform? With this new activity, beginning in summer 2019, the JPI HDHL aims to establish the Knowledge Platform, Food, Diet, Intestinal Microbiomics and Human Health. The overall aim of the Knowledge Platform is to foster transnational and multidisciplinary collaboration and networking in order to accelerate and develop intestinal microbiome research, related to human health, and increase its impact.

Activities: The platform will carry out joint multidisciplinary activities aimed at integrating expertise, knowledge, facilities and databases in areas such as biology, medicine, nutrition and (bio)informatics.

Added value of the JPI HDHL: The Knowledge Platform provides the unique possibility to connect all funded JPI HDHL researchers with other existing initiatives and relevant stakeholders in the human microbiome and health research area.

Key topics and societal impact

Research in Area 2: **Food for Health** will provide insights that support governments, industries and societies in making a major shift towards healthier and more sustainable food systems. It will also allow more targeted design, production and/or processing of foods, for populations, specific groups and individuals.

Insights from Area 3: **Diet, Health, and Disease** will be used to understand if, how and why sub-samples of populations, or individuals, respond differently to reformulated, healthier and more-sustainable food products. Potential health consequences, of environmental contaminants in foods, link the food value-chain to research in the field of **Diet, Health and Disease**.

Having examined the challenges across the food value-chain, the JPI HDHL has selected three key topics for research:

1. **Safe and sustainable food for a healthy diet:** covering bioactives, food safety and product reformulation
2. **Understanding nutrient utilization and metabolism:** covering bioavailability and the effects of food processing
3. **Food production for precision nutrition health:** covering personalized nutrition.

1. Safe and sustainable food for a healthy diet

Research needs to focus on how to create **healthy and sustainable dietary concepts that are consistent with sensory and lifestyle-related needs**. The challenge is to identify the right balance between food demand and resources in order to avoid reaching the limits of our planet. In particular, investigation into the affordability, availability and consumer acceptance of healthy and more-sustainable foods requires attention. The same applies to new approaches to more-targeted product development and reformulation (such as alternative protein sources) for the retail channel and for restaurants and other catering establishments.

Bioactives

Better use of raw animal and plant materials is essential in order to preserve natural resources. Bioactives, in the form of enhanced nutrients or non-nutrient food components, could provide great opportunities for innovation in food-processing technology. However, lack of scientific evidence on the health effects of new nutrient sources - for example from waste streams from the global food industry, including commercial fishing - has limited their use in the development of novel food products. More insights need to be gained on **new and known bioactives**, their interaction with the human genes and microbiota, and their effect in food matrices. This multidisciplinary research should involve nutrition scientists, physicians and food engineers across the food value-chain.

Product reformulation and foodomics

Research in the field of food and sensory science, as well as consumer research, is needed to enable targeted innovation and reformulation of food products and product portfolios, to add value in terms of health and sustainability, and of sensory properties. In particular the physicochemical structure, texture and sensory aspects of (reformulated) foods are crucial to consumer acceptance. These aspects also influence their willingness to buy, and therefore are essential in bringing a broad portfolio of healthy and sustainable food products to the market. The research should also consider issues such as portion size and salt, sugar and fat levels.

The emerging field of 'foodomics' has already substantially increased the knowledge of food composition and variability and has proven useful in quality control. Additional knowledge in this

field will accelerate the development of detailed food-composition tables, as well as foods which lose minimal amounts of bioactive constituents during processing. Foodomics is already triggering the exploration of new food sources and ingredients, and could be valuable in evaluating food authenticity and developing healthier and more-sustainable foods.

Food safety

Food safety is an important consideration in the development and production of healthy and sustainable food products. Global sourcing and production, with multiple stakeholders across the food value-chain, requires more-advanced monitoring and hazard assessment. The presence of toxins and environmental pollutants, and the transformation towards new, more sustainable marine and plant-based sources, further highlights the importance of new research in this field.

In collaboration with the food industry, potential toxic components or contaminants present and other biochemical and microbiological hazards in foods need to be identified. There is a need for the development of advanced technologies that facilitate quality monitoring and hazard assessment across the global food value-chain. Blockchain technology appears to offer exciting opportunities here. Alongside the risks of environmental pollutants, approaches should also consider contamination during production or via packaging material, and associated issues such as authenticity and traceability. The hazard potential involved in the use of side streams from agriculture and fisheries also needs further investigation, particularly the possible increased risk during food processing, but also the technological possibilities to purify side streams. Research should also be developed on predictive toxicology, such as the safety assessment of new processes and materials, the interactions between food contaminants and the microbiota and the internal exposure to environmental toxins released from fat tissue while dieting. These topics link closely to Area 3: Diet, Health and Disease.

2. Understanding nutrient utilization and metabolism

Bioaccessibility and bioavailability of nutrients

More research is needed to improve the understanding of nutrient bioavailability in the human body, including nutrient release from the food matrix, transport within the intestine and the delivery of nutrients to the site of absorption or utilization. This knowledge will provide new opportunities for the development of foods that, for example, affect nutrient transfer and microbiota composition in the gut and thereby modulate satiety and/or metabolism.

In addition, increased use of existing and exploitation of new plant and aquatic resources, could be a promising way forward in meeting demands for scarce ingredients. Examples include the extraction of bioactive ingredients such as long-chain n-3 fatty acids from algae, and plant proteins from agriculture waste streams. Knowledge needs to be gained on the health effects and safety of such components and how they can be efficiently processed in order to develop safe and nutritious foods that are accepted and appreciated by consumers.

The effects of food processing

The composition of a food, ingredient properties, processing and storage conditions affect the nutritional value and sensory properties of the end product. There is a strong need for research that gains a better understanding of these effects. This will substantially facilitate product development and reformulation. The whole food value-chain should be considered, from raw material to end product, in order to allow safe and standardized production processes. Research should also focus on prediction of the **effects of food structure and food processing** on the nutritional and sensory characteristics of foods. Insights in this field will allow the food industry to more-efficiently design foods tailored to consumers' nutritional needs and sensory demands. The emerging research field of **foodomics** might facilitate this process, by delivering fast and accurate methodologies for screening and characterizing the quality and composition of foods. A European, consensual definition of food processing combined with universally agreed metrics, are key to high quality research.

3. Food production for precision nutrition

European citizens generally consume excessive levels of salt, sugar and saturated fat. However, individual consumers display different metabolic reactions to these food components. Similarly, some consumers will respond physiologically to a dietary intervention but others will not (despite equivalent compliance). To date we have little or no understanding of this phenomenon, though this is vital in working towards precision nutrition. More research is needed to determine how precision nutrition can be of the most added value: food products targeting the dietary and sensory needs of specific groups - such as the elderly, pregnant women, children and people with a chronic disease - and perhaps even tailored to an individual's needs. Groups should be identified that respond similarly to nutritional interventions, as well as characteristics that individuals in these groups have in common, such as genetic polymorphisms or microbiota composition. The research should also include ethnicity, distribution channels and target-group specific marketing strategies.

Interconnectivity

Knowledge obtained in the **Citizens, Diet and Behaviour area** on the determinants influencing people's health behaviour and food choice is crucial for consumer acceptance and their willingness to buy such products, and thus essential for success on the market. The other way around, enhancing the knowledge of foodomics will contribute to better biomarkers for food intake, a crucial topic of Area 1: **Citizens, Diet and Behaviour.** Improved understanding of nutrient utilisation and the effects of food processing on amongst others the bioavailability of nutrients should feed into the research conducted in Area 3: **Diet, health and disease** which is targeted towards more insides in the biological mechanisms that can explain the relation between food and health. The research on potential health consequences of environmental toxins in food provides a strong link to Area 3: **Diet, Health and Disease**, while knowledge about food safety is also key to feed into interventions and education campaigns designed in the context of the **Citizens, Diet and Behaviour area**.

Area 3
Diet, Health and Disease

Targeting the mechanisms that prevent lifestyle-related disease and promote health

Background

A growing share of the population in Europe is suffering from some form of malnutrition, like deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients[36].
For clarification, in JPI HDHL we address malnutrition in this broader sense than solely as protein-energy deficiencies, characterized by the existence of undernutrition, coincident with obesity due to excessive calorific intake, and insufficient physical activity. Malnutrition is associated with increased risk of many diseases, from sarcopenia and osteoporosis to obesity, cardiovascular diseases, diabetes, certain types of cancer and neuro-degenerative diseases[2].

Metabolic diseases like obesity and diabetes, but also inflammatory bowel diseases and cognitive disorders such as dementia and depression are on the rise. In particular obesity is present throughout the whole life course. For every disease it is important to investigate the potential causes and contributing lifestyle factors separately in each different life stage. Specific prevention strategies tailored to the metabolic state and life circumstances of each age group are required.

Prevention of (childhood) obesity is key to reducing the incidence of chronic diseases. Although the prevention of childhood obesity is a key priority in research agendas all over the world, little progress has been made, to date, in finding effective strategies to tackle the issue[37].

However, even a well-balanced diet can cause negative health effects for individuals across all age groups. For example, an estimated one fifth of the general population suffers from adverse responses to food or believes they suffer from them[38]. Like malnutrition, food intolerance has consequences for quality of life and it increases medical costs, negatively affecting the economies of individuals, households and nations.

Current state of play

Nutrition and physical activity play important roles in processes related to health[39]. Nutrition and physical activity play important roles in processes related to health, such as metabolic programming, and might possibly interact with each other[40-41]. Mediation of inflammatory processes in the body could play a role in the development of certain diseases. However, the exact mechanisms behind how the interplay of diet and other lifestyle factors (such as physical activity and sedentary behaviour) affect bodily functioning are still largely unknown[42-43-44].

Mechanisms underlying undernutrition and over-nutrition, from molecular biology to human and social sciences, must be considered in order to provide an integrated view of complex behaviours such as food intake and physical activity/sedentary behaviour, their determinants and consequences.

Research has shown, for example, that physical fitness and nutritional needs differ across the continuum from health towards disease, and throughout the lifespan[42, 45].

Furthermore, there is growing evidence that not only the composition and quantity of foods consumed, but also the timing of meals and their interaction with the biological clock, have long-term effects on health[46]. In addition, current research shows that the regulation of appetite, body weight and metabolic homeostasis by the central nervous system is strongly influenced by nutrients, involving the gut and its interaction with brain functions[47-48]. Such complexity requires an interdisciplinary or systems approach to research, aiming at societal impact, innovation and economic growth, for the benefit of citizens from cradle to grave.

To further advance research efforts it is important to focus on vulnerable groups - including people from deprived sectors of society, people with chronic diseases and ethnic minorities - to prevent them from developing obesity, especially in life-changing transition periods such as pregnancy, birth to infancy, pre-school to school age, adolescence to early adulthood and in the years immediately preceding and following retirement.

WHAT HAS BEEN ACHIEVED SO FAR

MaNuEL

What is MaNuEL? The Malnutrition in the Elderly Knowledge Hub (MaNuEL) was a consortium of 22 research groups from 7 countries. The main objectives were building capacity, gaining knowledge, harmonizing research and clinical practice across Europe, and strengthening evidence-based best practice, all with regard to malnutrition in the elderly.

Achievements: The main objectives were reached and MaNuEL launched a toolbox, containing the main findings and recommendations for clinical practice and policy based on the MaNuEL project. The toolbox will contribute to the dissemination of the MaNuEL results.

Added value of the JPI HDHL: The international collaboration gave better insight into the current state of malnutrition in Europe, including guidelines and reimbursement of treatment in different countries. In addition, the toolbox can be used and distributed more easily throughout Europe.

ENPADASI

What is ENPADASI? The ENPADASI Knowledge Hub was a consortium of 51 research centres from 10 countries. The main objective was to deliver an open access research infrastructure containing data from a wide variety of nutritional studies.

Achievements: ENPADASI developed an open access research infrastructure and stored a large number of studies within it: 79 intervention and 24 cohort/observational studies. In addition, minimum requirements have been established, that sufficiently describe an observational study in the infrastructure, and a study assessment tool has been developed to evaluate the quality of the shared nutritional studies.

Added value of the JPI HDHL: ENPADASI partners of multiple European countries have been trained to use the system and will encourage nutritional researchers to share their future studies. The ENPADASI coordinator says: “Thanks to the JPI HDHL, we were able to establish a new international collaboration, making an exchange of knowledge possible that was essential for our project.”

Key topics and societal impact

The Area of **Diet, Health and Disease** will provide insights into the biological mechanisms behind malnutrition, and the physiological factors involved in food behaviour, and help define a *'healthy diet'* for specific target groups. This will support governments, industry and non-governmental organisations in the development of evidence-based and effective dietary interventions, targeting the general public, specific target groups - such as people with obesity and other chronic diseases - and perhaps, in a few years, individuals. The insights gained will also provide a basis for the development of targeted prevention and treatment strategies for food intolerances and allergies, as well as targeted product development and processing to prevent adverse reactions.

The JPI HDHL has defined three key research topics in the area of **Diet, Health and Disease**:

1. **Malnutrition and related diseases:** covering the identification of underlying mechanisms, precision nutrition concepts, as well as overweight and obesity prevention and treatment
2. **Physiology of food behaviour:** covering the regulation of food intake and the gut-brain axis
3. **Adverse reactions to food:** including food allergies and food intolerances

1. Malnutrition

Malnutrition, comprising all facets from macro- and micronutrient deficiencies to overnutrition and obesity, is a long-standing and highly relevant global problem for society and affects several population groups differently. Insufficient physical activity and an unbalanced calorific intake, together with unhealthy lifestyles and normal ageing of the population are the key factors involved. Both disease-related (e.g. cachexia related to cancer) and age-related (e.g. sarcopenia, frailty) malnutrition are equally damaging and need further investigation. In order to tackle this issue it is crucial to gain more insight into the biological **mechanisms that lead to malnutrition**.

Identification of underlying mechanisms

There is a need for advanced technologies that allow investigation of the effects of diets on each level: from the epigenome and transcriptome to the proteome and metabolome and, thus, the human phenotype. When embedded into the different life stages this research can reveal mechanisms or pathways that improve assessment of disease risk and help prevent or even treat lifestyle-related diseases.

Biomarkers for health

Sensitive and reliable biomarkers are vital in assessing the long-term health effects of diets and food products. These effects are currently difficult to assess, as demonstrated by, for example, the many rejections of health claims submitted to the European Food Safety Authority. Identification or development of a much broader palette of validated biomarkers could substantially facilitate this process. Biomarkers should reflect nutrition-related health status at both individual and group levels, and represent the effects of individual ingredients, food-products and/or diets.

Precision nutrition concepts for prevention & treatment of lifestyle-related diseases

A promising approach to tackling the different forms of malnutrition, is the development of more-targeted **nutrition within the vision of precision nutrition concepts**. The objective is to more-effectively tailor prevention and/or therapeutic strategies to meet the needs of specific target groups, or groups of individuals with similar phenotypes. An example could be nutritional concepts specially developed for the elderly, or people with a chronic health disorder such as diabetes or inflammatory bowel disease. This might be more effective than the 'one size fits all' approach - of the last few decades - that has not proven successful.

Definition of a healthy diet

Research is needed to understand the complex nutrition-gut-metabolism interactions and their impact on the health and disease risk for of people in general and specific subgroups (i.e. those in critical physiological or transitional life periods such as pregnancy, lactation, infancy, childhood, retirement and old age, or people with chronic diseases). Insights in this field are a prerequisite for the development of more-targeted dietary recommendations in the continuum between health and disease. As a healthy diet is not necessarily the same as a sustainable diet, a diet that is both healthy and sustainable is a logical focus.

Overweight, obesity prevention and treatment

Effective strategies, for the prevention and treatment of obesity and related metabolic diseases, must target all age groups and use a whole-life approach that covers all critical transition phases, by combining knowledge and expertise from all three research areas within the JPI HDHL. It is important to investigate how interventions can be implemented effectively within healthcare systems, as this has the potential to deliver huge, and relatively short-term, impacts.

It is crucial to better understand the role of early environmental exposure to an unhealthy diet and/or low levels of physical activity, in the development of obesity, diabetes and related diseases at any life stage. This will help optimise foetal and early postnatal development, with the goal of preventing excessive weight gain during infancy and childhood.

In recent years research has focused mainly on preventing obesity in childhood. Adolescents, too, are an important target group; during adolescence hormonal changes and rapid growth might offer potential for metabolic (re)programming, while dietary behaviour often substantially changes. Furthermore, scientists should also look into how adults can maintain a healthy body weight and prevent weight gain by investigating the mechanisms that lead to obesity in later life, especially during life-changing events, such as young adults moving out from home, people starting a family, or older people transitioning into retirement.

2. Physiology of dietary behaviour

Dietary behaviour, such as making food choices and controlling intake, includes highly-complex processes that are affected by a variety of physiological (and psychological) factors, which in turn have an impact individual health status. Energy balance and metabolic homeostasis are controlled by neurological and endocrine processes, which in turn are strongly influenced by diet and physical activity.

More research is needed to clarify the mechanisms by which dietary factors and physical activity affect central nervous system and endocrine processes, such as the release of satiety hormones, and the induction of feelings of reward, and how this causes alterations in food choices and food intake control; changes that might condition someone to develop obesity and other metabolic disorders.

Further, there is growing evidence that diet has an effect on cognitive functions such as perception, reasoning, and memory. It also affects cognitive development in early childhood, as well as the maintenance or decline of cognitive functions in later life. This interrelation between diet and cognitive functions appears to be, at least, partly mediated by a direct interaction between the gut, the gut microbiota and the brain (gut-brain axis). Indirect underlying biological mechanisms, including dysregulated metabolism, inflammation, the immune system and its interaction with the brain, are soundly described. However, direct causal mechanisms, rather than associations, need to be established. For example, the putative impact of metabolites of the gastrointestinal microbiota on health needs to be fully elucidated.

Regulation of food intake

Food intake, food choice and eating behaviour are partly controlled by nutrients present in the gastrointestinal tract and the central nervous system, in a process called nutrient-signalling. Cognitive control of dietary behaviour also plays a part. For example, the role of technology and (digital) marketing targeted at children that shapes both healthy and unhealthy behaviour, is of much interest. However, the implications of these interactions are still unknown. There is a particular need for research into the association between neurological processes, micro- and macronutrient composition of the diet, and health issues such as obesity, metabolic disorders and degenerative diseases.

Different kinds of foods and meal compositions, the frequency and timing of consumption and physical activity might affect a person's internal clock and health status, since every organ has a time of the day at which it functions at its best. For example, there is clear evidence that feelings of hunger/satiety and energy production vary according to a circadian pattern. The specific time of day when food is consumed could influence weight gain, for example.

More research is needed on the interaction between circadian timing of intake and potential health outcomes, as indicated by the weight gain example, such as the development of metabolic syndrome or cancer. The role of physical exercise (muscle activity), as an important chronobiological cue to reset the circadian rhythm, also merits further consideration. A deeper understanding of the effects of biological rhythms, on the response to nutrition and physical activity, will offer guidance in the optimization of dietary recommendations and development of new prevention strategies.

Gut-brain axis

The composition and activity of human gut microbiota have been linked with brain function and neuropsychological diseases. Diet is one of the main factors modulating the composition and function of the gut microbiome, but the mode of action is not yet fully understood. More research, as well as a harmonization of research approaches, is needed to better understand how diet and lifestyle influence the composition of the gut microbiota and thereby health, especially the development, maintenance and decline of cognitive function throughout life. In addition to the microbiota, the gastrointestinal mucosa has been shown to have a major impact on metabolic processes after food intake. This regulation includes a large number of yet-to-be-identified endocrine regulators, and the possibility of neural regulation via the gastrointestinal tract.

3. Adverse reactions to food

Adverse reactions to food, including food intolerances and allergies, are becoming increasingly common. There is a clear need for a better understanding of the underlying mechanisms of adverse reactions, in their different forms, as well as the (perceived) increase in food intolerances. One possible hypothesis is that breeding, food processing and additives, might expose new epitopes of allergens by altering the food matrix. Psychological factors, including the perception of foods, might also play a role in the increased incidence of intolerances and adverse reactions.

Food allergies and food intolerance

The relationship between food processing and food allergy or food intolerance merits investigation at the European level. Therefore, JPI HDHL seeks to underpin approaches that can define the extent to which product reformulation, food processing and eating habits can attenuate the risk of adverse reactions to food. Such reactions include both immune-mediated food allergies and non-immune-mediated food intolerances. For the second group in particular, not all reported symptoms are caused by food intolerance. Therefore, it is difficult to estimate how many people are truly affected, which points to the need for stronger evidence-based data. More research is needed to identify potential allergens and to understand how they work.

Interconnectivity

Knowledge about biological processes that influence dietary behaviour deriving from this research area, such as the regulation of food intake should feed into both Area 1: **Citizens, Diet and Behaviour** and Area 2: **Food for Health**. This knowledge can be key in creating a healthy food environment both in relation to using this knowledge towards healthier food processing or food products as well as to minimise triggers that influence the regulation of food intake in a negative way. There is a strong link between biomarkers for health and the biomarkers for food intake listed in Area 1: Citizens, Diet and Behaviour and, furthermore biomarkers for health are important in light of food production and the possibility to work towards health claims. Furthermore new knowledge about the underlying mechanism of precision nutrition concepts should feed into the **Food for Health** area to work towards food products targeting specific population groups. Furthermore a better understanding of food allergies and intolerances as well as a better understanding of the underlying mechanism will link closely Area 2: **Food for Health**, both in regard to causal relations as well as targeted products for example for certain age groups or people with lifestyle-related diseases.

Ensuring real societal impact

Ensuring real societal impact

The European Research Area in food, nutrition and health is becoming increasingly complex. A wide range of distinct and discipline-specific criteria and procedures are used for analytical and physiological assessments, and both nutrition and food sciences are driven by progress in many different fields. This includes, for example, genetics, epidemiology, biobanking, biomedicine, molecular biology, systems biology and material sciences, but also advances in analytical techniques, biotechnology and nanotechnology, chemometrics and IT. Regulatory demands, in the field of health claims and novel foods, require comprehensive safety assessment procedures and scientific evidence from human studies. In addition to all these fields of expertise, the European Research Area should integrate research expertise in agriculture, marine culture, food production and climate change/ the environment, biology, psychology, social sciences and epidemiology. This will ensure a holistic approach that connects the societal challenge of reducing the incidence of lifestyle-related chronic diseases with the aim of ensuring worldwide food and nutrition security.

The societal challenge of JPI HDHL involves a wide variety of stakeholders: representatives of Non Governmental Organisations (NGOs), (public) healthcare professionals, consumers, industry, food retailers, research and development, education institutes and policymakers (European and national, Research and Innovation and thematic). To ensure JPI HDHL investments can be translated into actual health improvements, JPI HDHL works towards an integrated multi-sector approach embracing education, healthcare, agriculture, the environment, the food and drink industry, transport, advertising, commerce and, of course, consumers. This is essential to position food, nutrition and related public-health policy and research evidence sufficiently high on political agendas. Furthermore it ensures that the knowledge needs of different societal actors are well reflected in the research activities funded by JPI HDHL.

To ensure real societal impact, JPI HDHL has highlighted three interlinked themes, of significant importance for all funding and non-funding activities in the area of research on food, nutrition and health:

(1) Improving the efficiency of the research domain

(2) Raising the scale and ambition and structuring the research area

(3) Communication and education

Increasing the accessibility, efficiency and effectiveness of the food, nutrition and health research domain

An open and sustainable European data infrastructure, and stimulation of the circulation and reuse of scientific data, are vital in order to increase the impact of research investment. Research infrastructures — the facilities, resources and services used by research communities to conduct research - are the backbone of any research domain and crucial to efficiency. They make state-of-the art insights and technologies available to new generations of researchers and industry, thereby accelerating developments in science, technology and business.

Research Infrastructures can be ‘single-sited’, ‘virtual’, or ‘distributed’. They enable data collection, management, processing, analysis and archiving and can include, for example, large-scale scientific equipment, skilled services personnel, competence development and outreach, knowledge-based resources such as archives and scientific data, and e-infrastructures, such as databases, computing systems and communications networks. Standardization of data, data collections and

methodologies are another aspect of research infrastructures needed in order to define best practices in science and related business development. Standardization measures require frequent updates to avoid impeding development and progress. Nutrition recommendations, and standards for analytical procedures, are typical of measures that could be standardized.

FAIR data principle and open-access strategies

In 2016 the JPI HDHL adopted the FAIR data principles, meaning that all the research funded via JPI HDHL must respect the FAIR data principles. In addition, in its call texts, JPI HDHL strongly encourages all applicants to the joint funding actions to make use of existing data in their proposals, benefitting from implementing the FAIR data principles.

FAIR refers to the Findability, Accessibility, Interoperability and Reusability of data. Findability refers to data that are assigned with a global unique and persistent identifier, with rich metadata that clearly and explicitly include the identifier of the data it describes and are registered or indexed in a searchable resource. Accessibility requires that (meta)data are retrievable by their identifier using a standardized communications protocol, which is open, free and universally implementable, and allows for an authentication and authorization procedure, where necessary. Metadata should be accessible, even when the data are no longer available. Interoperability entails the use of formal, accessible, shared and broadly applicable language for knowledge representation, the use of vocabularies that follow FAIR principles for the inclusion of qualified references to other (meta)data. Reusability of data demands that (meta) data are richly described with a plurality and relevant attributes, are released with a clear and accessible data usage license, are associated with detailed provenance, and meet domain-relevant community standards.

Open-access policies

For the JPI HDHL, knowledge sharing, including open access to research output, is crucial to addressing the societal challenges the JPI works on. The JPI HDHL expects its applicants to consider their exploitation and dissemination strategy at the draft stage of their proposal, and to develop a data management plan and consortium agreement at the start of the project. JPI HDHL respects and follows the open-access policy aims of the European Commission, meaning that all publicly-funded research should be openly accessible. This is underpinned by the philosophy that open science and open access will contribute to better and more-efficient science and to innovation in both public and private sectors.

Towards a research infrastructure

The agricultural and healthcare sectors already have (advanced) research infrastructures in place. However, an infrastructure to study the relationship between food, nutrition and health does not exist, as acknowledged by the European Strategy Forum on Research Infrastructures (ESFRI).

Current state of play

Two initiatives explicitly work towards delivering a research infrastructure (or RI facilities) within the domain of food, nutrition and health: METROFOOD-RI and FNH RI.

METROFOOD-RI, aims to provide metrology services in food and nutrition, comprising an important cross-section of highly interdisciplinary and interconnected fields throughout the food value-chain. These include agrifood, sustainable development, food safety, quality, traceability and authenticity, environmental safety, and human health. METROFOOD-RI will consist of physical and electronic infrastructures to coordinate and integrate existing networks of factories, laboratories, experimental fields and farms for crop production and animal breeding, small-scale factories for food processing and storage, and kitchen-labs for food preparation. METROFOOD-RI is currently in the Preparatory Phase of the ESFRI roadmap, which includes the objective to attain firm commitments from additional countries, to better align governance and financial-management models, and to set up the legally-binding agreements necessary to establish ERIC**** status. The Implementation Phase is planned to start in 2021, with full operation expected by 2024[49].

The **Food, Nutrition and Health Research Infrastructure** (FNH-RI) aims to develop a European platform for data, tools and services for research into food, nutrition and health. In this platform the consumer is the link between the agrifood and health sectors. The platform will provide research data, tools and services directed at food production and sustainability, consumer behaviour, nutrition and health. A unique aspect is the integration of consumer data into the platform. Traditionally, research data has been collected through projects and studies. New technologies have made it possible for consumers to collect large amounts of varied data about themselves and their environments. This new source of data is enabling research to expand beyond traditional ways of data collection. The FP7-funded project **Eurodish** and the Horizon2020 project **Richfields** are at the forefront of the self-collected data movement. The FNH-RI initiative is currently moving from the design phase into the preparatory phase. The ambition is to have the research infrastructure fully operational by 2024[50].

The JPI-HDHL project ENPADASI is one of the latest in a series of European efforts to define and build an infrastructure to study the relationship between food, nutrition and health. Its DASH-IN (DAta SHaring In Nutrition) structure may be seen as an early prototype. It allows connectivity between distributed databases containing structured records of nutritional studies. There is no limit to the study design. DASH-IN is compliant with the latest data-safety legislation and compatible with FAIR principles. The ENPADASI project has delivered a minimum-requirement for information content in study data to be entered in DASH-IN, a first ontology for nutrition science, and an online data-quality assessment tool. There remains a need to optimize this structure, to make it sustainable while requiring minimal amounts of man-hours, to create many more nodes at all European universities, and to implement it into the planning, grant and publication systems.

Future proof

It is important to carefully identify what the fields of nutrition, food science and related health and social sciences would require from such a common infrastructure or infrastructures, and how to build them in the most effective way. Most modern infrastructures are e-resources that allow information to flow to those who need it. However, these sources still need manpower to update and curate the information they deliver. Food-composition databases, gene databases and large chemical, proteomic and metabolomics databases are typical examples of infrastructures where sustainable knowledge is gathered, stored and retrieved. The latest generation of infrastructures allows users to retrieve information that is tailor-made to their data or problem. They allow searching and combining information in an interactive way to speed up scientific procedures. These infrastructures are typically add-ons to databases or *'spider'*-structures (such as ChemSpider) that allow automatic search and data analysis, simultaneously across multiple databases. Literature search engines and web crawlers are well-known examples.
The wish is for an integration tool that allows access and interrogation of all the collective knowledge

**** The community legal framework for a European Research Infrastructure Consortium (ERIC) is a specific legal form to facilitate the establishment and operation of research infrastructures with European interest..

in the field, in a structured way. A prerequisite is that this collective knowledge is online and well-organized, via databases, standardized methods and tools for tailor-made analyses.

The role of JPI HDHL

The establishment of a research infrastructure is beyond the remit of JPI HDHL, although, at the same time, it is of key importance to deliver towards the vision of the initiative. Therefore JPI HDHL will invest in a dialogue with the involved stakeholders from existing research infrastructures and those currently in development, by clearly defining the needs of the research community and the JPI. Furthermore, JPI HDHL will contribute to components and developments that help establish the desired research infrastructure and/or support the research community to utilize existing research infrastructures where possible. The initiative will also search for alliances with actors that might accelerate development of such an infrastructure.

JPI HDHL sees the following requirements as key for a research infrastructure in the field of food, nutrition and health:

- to connect with or build on existing research infrastructures where possible
- be immediately useful for a larger community (highly needed)
- strengthen efforts for reuse of existing (meta)data sets by including this as a requirement in upcoming funding activities to benefit from the implementation of FAIR data principles
- include a platform for harmonisation and standardization in nutrition and food research and technology, for data storage and handling, and for open sharing of nutrition and food-research-specific information. This will provide a basis for more-sustained research, conducted in a collaborative setting with experts from all over Europe, and support interaction with leading scientists from countries outside the European Research Area
- include capacity-building in big data science and the potential impact of big data science on prevention strategies of lifestyle-related diseases at individual and population levels
- receive broad support (might already exist as there are multiple competing 'prototypes' in different research environments)
- have a self-sustainable business model or at least be supported by strong demand

Responsible Research and Innovation

Responsible Research and Innovation is the ongoing process of aligning research and innovation to the values, needs and expectations of society[51]. Citizen science, and participatory research and education, could reduce the gap between science and society. To align the research activity with the values, needs and expectations of societal actors (policymakers, citizens, third-sector organizations, industry), and following the Rome Declaration on Responsible Research and Innovation in Europe, JPI HDHL promotes Responsible Research and Innovation (processes) within its activities. This entails the engagement of societal actors throughout the whole research and innovation process. This will support JPI HDHL funding and non-funding activities by making them more:

- **Diverse and inclusive:** to include, from the beginning, the key stakeholders in research and innovation, in planning, decision making, communication and dissemination.
- **Anticipative and reflective:** envisioning impacts and reflecting on underlying assumptions, values and purposes to better understand how research and innovation shapes the future.
- **Open and transparent:** communicate, throughout the process, in a balanced, meaningful way to enable public analysis and dialogue, improving Research and Innovation visibility and appreciation.
- **Responsive and adaptive to change:** be able to modify modes of thought and behaviour, and adapt overarching structures, in response to changing knowledge and new perspectives.

Evaluation and monitoring

Individual joint actions, as well as projects that are funded under the umbrella of the respective joint actions, have their procedure and outcomes monitored and evaluated. The results of the monitoring and evaluation activities are used to improve the procedures and to build a sound basis for future activities. JPI HDHL has developed a general evaluation framework and includes, for each joint action, specific questions related to the expected outcomes. The JPI HDHL is evaluated every two years, on its process, output and outcomes through self-evaluation and also via evaluations from the High Level Group for Joint Programming. The first external impact evaluation of JPI HDHL is expected to be released by the end of 2020. The JPI HDHL advisory boards, the management board, the organizations engaged in the secretariat, as well as reviewers and applicants are examples of groups that are approached when a (self)evaluation is performed. The wider involvement of the member countries and the European Commission through the High Level Group on Joint Programming, and the exchange between the 10 Joint Programming Initiatives will also ensure that recommendations will be taken into account when developing the evaluation framework.

Raising the scale and ambition and structuring the landscape

Europe has a strong track record in nutrition and food sciences. Research activities, however, are highly fragmented and, in certain areas and countries, the volume of research is below the critical mass needed for a sustained and competitive future. At both national and international levels there are many links to research relevant to the societal challenges addressed by JPI HDHL. However, the research area that deals with the links between nutrition and health and nutrition-related public health interventions, often falls in between the agricultural and health domains and so risks underinvestment. JPI HDHL advocates the importance of holistic research to tackle these societal challenges. This SRA provides a framework which also serves to align and reduce fragmentation in research funding at national and international levels.

Integration and synergies among networks and initiatives

In order to increase the impact of JPI HDHL, and due to its trans-disciplinary and applied objectives, it is critical to enhance connections with existing large initiatives and institutions at the European and global level. By doing so, it will be possible to establish a Food and Nutrition stakeholder platform in Europe, based on life and social sciences throughout the food value-chain. A first inventory of more than 100 such initiatives and structures, related to the scope and objectives of JPI HDHL, have been identified and described on the website, displayed according to the JPI HDHL research areas. It is important to facilitate the connection between the JPI HDHL and different scientific and policy areas (e.g. nanotechnology, water, agriculture, economics) that are associated with the JPI societal challenge, in order to facilitate trans-disciplinary research.

The future will require a more-coherent and comprehensive coordinated approach from policymakers, while at the same time putting issues of health and healthy and sustainable lifestyles at the centre of these policies (e.g. education, innovation, agriculture, city-planning). In addition, increased attention is needed to develop a global perspective on policy and the issues addressed by the JPI HDHL. Through its various bodies (scientific and stakeholder advisory boards, management board) the JPI represents a network spanning many (European) countries and all relevant scientific, technological, business, policy and end-users activities.

In addition, the JPI is committed to interacting as effectively as possible with relevant European initiatives and programs for optimal information flow and transparency and to create valuable synergies.

The following links merit particular attention:

- With the ***JPIs FACCE*** and ***OCEANS*** (Agriculture, Food security and Climate change; Healthy and Seas and Oceans), and with related ERA-NETs from Societal Challenge 2 of Horizon2020 (e.g. ***SUSFOOD2*** on sustainable food production and consumption).
  Following the grand debate at Expo Milano (2015), and several scientific workshops, a common position paper from the three JPIs, *Food and Nutrition Security: a multi-disciplinary integrative food system approach*, was published. Ensuring Food and Nutrition Security is a complex issue, requiring an integrated food-systems perspective. Together, the three JPIs cover the necessary scientific fields and ensure integrated research across the whole food system, and therefore have the opportunity to create a bigger impact on the societal challenges related to Food and Nutrition Security. This research is expected to contribute to the implementation of the European Commission's FOOD 2030 strategy (see below) and also to the United Nations Sustainable Development Goals.
  The implementation options include building a Knowledge Hub, defining a roadmap for production systems, and improvements to Food and Nutrition Security, in the areas of production, processing and transformation and food consumption.

- With the ***FOOD 2030*** policy framework of the European Commission (DG Research and Innovation), whose objective is to increase the contribution of European Union Research and Innovation to the major global challenge of ensuring Food and Nutrition Security. The strategy has four priorities: Nutrition for Sustainable and Healthy Diets; Climate Smart and Environmentally-Sustainable Food Systems; Circularity and Resource Efficiency of Food Systems and Innovation and Empowerment of Communities.
  JPI HDHL, together with FACCE and Oceans, is strongly involved in the Coordination and Support Action (CSA) FIT4FOOD2030, which develops new instruments such as Policy Labs, City Labs and an EU Think Tank. The final objective is to create a sustainable multi-stakeholder FOOD 2030 platform for transformed Food and Nutrition Security related Research and Innovation systems.
  In connection with FOOD 2030, HDHL also participates in the Standing Committee on Agricultural Research - Strategic Working Group on Food Systems, an initiative from Member States.

- With the actions of the DG Santé (Health and Food safety) of the European Commission and the ***High Level Group on Nutrition and Physical activity***, in relation to prevention of disease and promotion of health. So far, information has been exchanged on knowledge gaps and research priorities from the public health policy perspective, and on how this relates to the SRA of HDHL. DG Santé is represented in the Stakeholder Advisory Board of the JPI.

- With different ***initiatives or platforms*** involving professionals ***from the Food industry***.
  The European Technology Platform, Food for Life (with the support of FoodDrinkEurope), and the European Technology Platform, Plants for the Future, are active members of the JPI's Stakeholder Advisory Board.
  There are also links with EIT-FOOD, a Knowledge and Innovation Community supported by the European Institute of Innovation and Technology (EIT), based on a pan-European consortium devoted to entrepreneurship and innovation in the food sector.

- With different associations or organizations, which open the possibility to improve ***communication and outreach towards the general public***. This is done through several members of the Stakeholder Advisory Board, such as the European Food Information Council (EUFIC), the European Public Health Association (EPHA) and the European Federation of the Associations of Dieticians (EFAD).

- With other ***important stakeholders at the global level***. Alignment at national, European and global levels is also an objective for the JPI. For instance, comparative analysis and exchanges have taken place concerning the USA Roadmap for Nutrition, issued by their Interagency

Committee on Human Nutrition, involving the National Institutes of Health (NIH) and the US Department of Agriculture.

Communication, dissemination and education

In order to reach its objectives, JPI HDHL needs to build and maintain an extensive network of stakeholders. The core principle of the JPI HDHL is to facilitate coordination between policymakers in the countries involved with a view to support collaboration between scientists and other stakeholders to generate new scientific knowledge, share existing knowledge and expertise, and bring together important datasets in the areas of food, nutrition and health. The outcomes of the Joint Actions of JPI HDHL will create a strong knowledge base for policy within the JPI HDHL countries, the European Union and beyond. The other way around knowledge needs articulated by societal actors can feed into the JPI HDHL funding and non-funding activities. Therefore, efficient communication and dissemination to all key actors is most crucial for success.

Communication and dissemination

Communication and the dissemination of research outcomes are essential to ensuring the largest possible impact from JPI HDHL activities. Across all the scientific areas, policymakers, the food industry and the general public should be reached in order to translate results into tangible benefits for the various stakeholders.
Transfer of knowledge and technology is a driver of innovation and a key-focus for improvement in industry from multinationals to small and medium enterprises (SMEs). Communication is also important to optimize interaction between themes, which allows the various stakeholders to gain maximum benefit from ongoing activities and insights.

For example, enhanced flow of knowledge and research understanding between the research areas of **Citizens, Diet and Behaviour, Food for Health** and **Diet, Health and Disease** will facilitate maximal translation of JPI HDHL funded research. Through the activities mentioned in its implementation plans, JPI HDHL creates opportunities for the communication and dissemination of ongoing and completed research activities. This also allows for interaction and debate between different scientific communities, and between scientists and other societal actors - policymakers in particular.

Given the scope of JPI HDHL, there is a huge variety of stakeholder groups with a huge variety of needs: the scientific community, policymakers, research funding bodies, food producers, industry, public health organizations, healthcare providers, consumer organizations and society in general. Alongside its implementation plan, JPI HDHL publishes its communication strategy, with the aim to improve and strengthen the visibility of JPI HDHL and effectively disseminate its activities and results among its stakeholder community. The key stakeholders not only receive information about JPI HDHL actions and outputs, but also actively contribute to the implementation of the JPI HDHL objectives and the realization of its vision.

Improve education, training and scientific career development, in collaboration with stakeholders

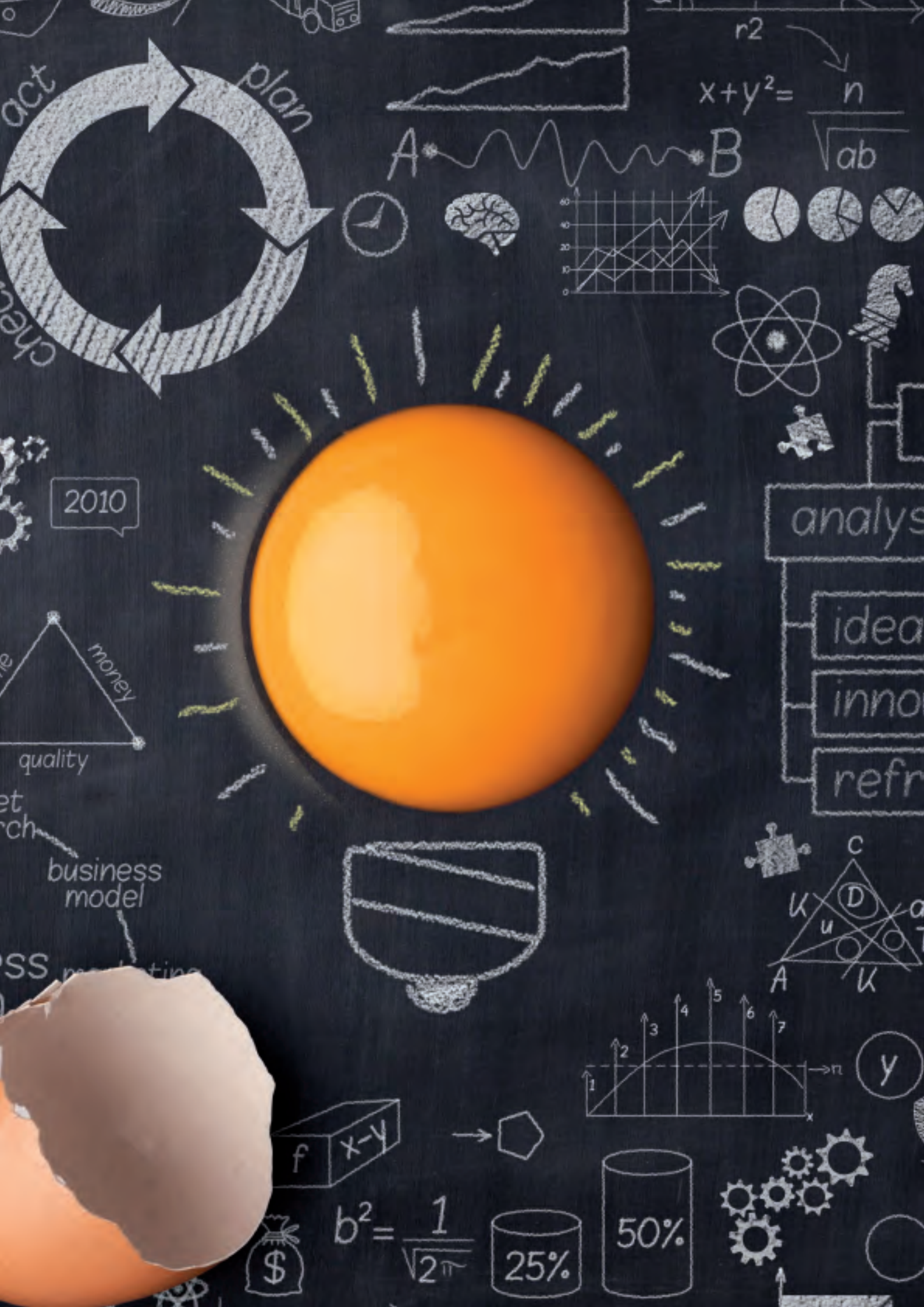
JPI HDHL activities go beyond the classical borders of scientific disciplines. Diversification and specialization are intrinsic features of modern science. Yet, societal challenges require trans-disciplinary competences and better interaction between different science cultures (biosciences, human and social sciences) combined with a better understanding of the needs of key players in the global food system. To achieve more impact from the research, training of the scientists must be connected to the needs of policy, industry, (public) health professionals and citizens. The opportunity

to develop networks of early to mid-career researchers is very important. Specific investment in training, within and outside of research projects, will help build skills among individual researchers and the ability to conduct large-scale research with multiple countries from Europe and beyond.

A particular concern is that highly-specialized scientific disciplines have established ranking and incentive systems for high-impact publications, whereas the multidisciplinary approaches and knowledge translation areas are rarely able to meet these criteria. To ensure that the research areas covered in this JPI are attractive for top students and scientists, the reputation of the science disciplines involved needs to be improved. This also applies to science career perspectives and to the mobility of researchers from participating countries. JPI HDHL will foster alliances with key actors in the Research and Innovation landscape of food, nutrition and health as well as within the JPI community to work towards breaking down this barrier.

Key players

Stakeholders can become key players and, in this way, play a significant role in achieving the overall vision and goals of the JPI HDHL. The key players of JPI HDHL, their roles and how they can participate in the implementation of the SRA is described in the JPI HDHL Implementation Plan, published every 2-3 years.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Annex 1
List of Acronyms

DASH-IN	DAta SHaring In Nutrition
DEDIPAC	Determinants on Diet and Physical Activity Knowledge Hub
ENPADASI	European Nutritional Phenotype Assessment and Data Sharing Initiative Knowledge Hub
ESFRI	European Strategy Forum on Research Infrastructures
FAO	Food and Agriculture Organisation
FOODBALL	Food Biomarkers Alliance
JPI	Joint Programming Initiative
JPI FACCE	Joint Programming Initiative Agriculture, Food security and Climate change
JPI HDHL	Joint Programming Initiative A Healthy Diet for a Healthy Life
JPI OCEANS	Joint Programming Initiative Healthy and Productive Oceans
MANUEL KH	Malnutrition in the Elderly Knowledge Hub
PEN	Policy Evaluation Network
SRA	Strategic Research Agenda
WHO	World Health Organisation

Annex 2

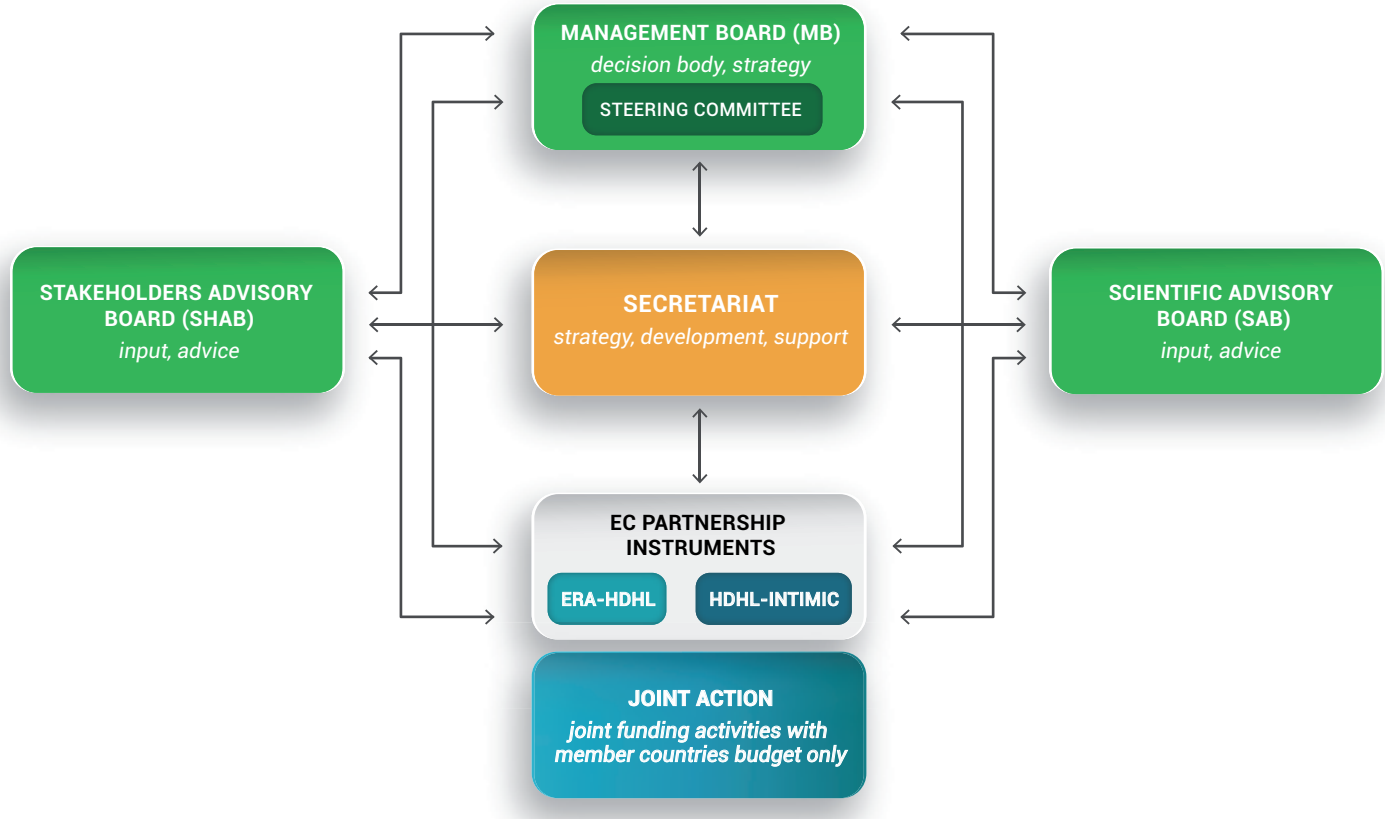
Overview of JPI HDHL joint funding activities

CALL	NUMBER OF FUNDED PROJECTS	ACRONYMS OF FUNDED PROJECTS
DEDIPAC (2013): Determinants of Diet and Physical Activity (Knowledge Hub)	1	DEDIPAC
ENPADASI (2014): European Nutritional Phenotype Assessment and Data Sharing Initiative (Knowledge Hub)	1	ENPADASI
BioNH (2014): Biomarkers for Nutrition and Health	2	FOODBALL MIRDIET
Intestinal Microbiomics (2015)	6	ArylMUNE, DINAMIC, EarlyMicroHealth, EarlyVir, GI-MDH, MaPLE
Food Processing for Health (2015)	2	LONGLIFE PROHEALTH
MaNuEL (2015): Malnutrition in the Elderly Knowledge Hub	1	MaNuEL

CALL	NUMBER OF FUNDED PROJECTS	ACRONYMS OF FUNDED PROJECTS
NutriCog (2015): Nutrition and Cognitive Function	5	AMBROSIAC, D-CogPlast, iCASE, MiTyrAge, SELENIUS
ERA-HDHL BioNH (2016) Biomarkers for Nutrition and Health, co-funded call	12	ALPHABET, BioFN, BioNUGUT, CABALA Diet and health, DERIVE, FAME, FiberTAG, HEALTHMARK, OXYGENATE, SALAMANDER, SALIVAGES, VALID
Working Groups on Diet Related Diseases	1	(@OBEDIS)
PEN (2017): Policy Evaluation Network (Knowledge hub)	1	Effectiveness of existing policies for lifestyle interventions - Policy Evaluation Network (PEN)
HDHL-INTIMIC (2017) Co-funded Call: Interrelation of the Intestinal Microbiome, Diet and Health	11	DiGuMet, DIME, Di-mi-Liv, earlyFOOD, FATMAL, GUTMOM, meaTIc, MEDIMACS, MICRODIET, OCTOPUS, TransMic
ERA-HDHL (2018) Nutrition & the Epigenome	6	DIMENSION, PREcisE NutriPROGRAM, EpiBrain, HEROS, DIFAMEM
HDHL-INTIMIC (2019) Knowledge Platform on Food, Diet, Intestinal Microbiomics and Human Health	Call in progress	Call in progress
ERA-HDHL (2019) Knowledge Hub on Food and Nutrition Security	Call in progress	Call in progress
HDHL-INTIMIC (2019) Impact of Diet, Food Components and Food Processing on Body Weight Regulation and Overweight Related Metabolic Diseases (METADIS)	Call in progress	Call in progress

Annex 3

Governance Structure JPI HDHL



Management Board and Steering Committee

The MB is the decision making body of JPI HDHL. The members of the MB are representatives of their country and have the governmental mandate — they are nominated by a competent authority. To become a member of the MB a country has to sign the MoU of JPI HDHL. Each member country of JPI HDHL has one vote in the MB. The MB operates according to the Terms of Reference which the

members agreed upon. The Steering Committee — consisting of the independent chair, vice chair and two elected MB members — deals with daily and urgent issues on behalf of the MB and is the linking pin between the MB and the secretariat as well as the MB and the JPI HDHL related Partnership instruments with the European Commission (currently two ERA-NET Cofunds). Please see the JPI HDHL website for an overview of the member countries of the management board of JPI HDHL and their representatives.

Advisory Boards

To support the MB in its strategy development and implementation activities, two advisory bodies have been established: the **SAB** and the **SHAB**. The members of the advisory boards are shown on the JPI HDHL website.

The **SAB** consists of 15 scientists who have a seat in the SAB on a personal title. The expertise of the SAB is equally divided between the three areas of the SRA — five scientists for each area. The SAB members have been elected by the MB and work according to their Terms of Reference, drafted by the MB in close collaboration with the SAB. A rotation schedule for the SAB members is in place.

The **SHAB** consists of 15 stakeholder organisations with an international profile that are active in the field of JPI HDHL. Representatives of these organisations take a seat in the SHAB on behalf of their organisations. Together, the SHAB covers the different stakeholder perspectives e.g. consumers, (public) health(care) professionals, industry and science. The SHAB organisations have been selected by the MB of JPI HDHL and the SHAB works according to their Terms of Reference, drafted by the MB in close collaboration with the SHAB.

JPI HDHL Secretariat

The secretariat of JPI HDHL forms the office of JPI HDHL. It is the central contact point of JPI HDHL and circulates information to the MB of JPI HDHL and the secretariats of the SAB and the SHAB. The secretariat is coordinated by the project manager of the CSA of JPI HDHL and is — together with the SC — responsible for a good match of the CSA activities with the decisions made by and developments within the MB.

Partnership instruments

JPI HDHL makes use of EC Research and innovation Frameworks partnership instruments, like ERA-NET Cofunds. These have a primary aim to create synergy between funding of the JPI HDHL countries and funding made available by the EC on a specific theme. Furthermore, these instruments create a supporting infrastructure to implement international research funding activities.

Annex 4

Hierarchy of the JPI HDHL strategic documents

VISION DOCUMENT

- Developed in the start-up phase of JPI HDHL in 2011
- Provides the basis of the activities of JPI HDHL

STRATEGIC RESEARCH AGENDA

- The roadmap provides a framework for coordinated and structured research activities in order to achieve tangible societal impact. It offers individual member countries a solid basis for goals, objectives and strategies.
- Though written from the perspective of its members, the SRA can also inspire governments, non-governmental organizations and industries, around the world, to align their research and policy-making activities.
- Updated every 5 years

IMPLEMENTATION PLAN

- The operational plan which Includes the ambitioned activities for a set period of 2 to 3 years including:
    - the topics for the funding activities
    - non funding activities
    - Key Performance Indicators

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Contributors
JPI HDHL Scientific Advisory Board

Marie Alminger
Stephan Bischoff
Molly Byrne
Mark Conner
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Eva Falch
Edith Feskens
Emmanuelle Kesse-Guyot
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Friederike Bathe, DLR
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INRA
ZonMw

Editors
James Campbell
Lisette de Jong

Coordination
Chrissie Brierley, ZonMw
Beatrice Darcy-Vrillon, INRA
Jolien Wenink, ZonMw

Lay-out and design
Claudia Pica, www.grafica@claudiapica.it

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