



**ADVICE FOR 2016/2017
OF THE HORIZON 2020 ADVISORY GROUP
FOR SOCIETAL CHALLENGE 1,
“HEALTH, DEMOGRAPHIC CHANGE AND WELLBEING”**

July 2014

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ADVICE 2014 OF THE HORIZON 2020 ADVISORY GROUP FOR SOCIETAL CHALLENGE 1, “HEALTH, DEMOGRAPHIC CHANGE AND WELLBEING”

Executive Summary

We need research to strengthen health care and public health, and as a driving factor for innovation and investment in industry, education and training in Europe. At the moment health care costs are rising, the population in Europe is ageing, and research solutions are needed to meet the challenges of tomorrow. Major improvements in health care have come about because of social and public health advances, such as piped, clean water, sanitation and better nutrition and housing, but also due to the impressive progress of modern medicine and public health. However large inequalities still exist in the provision of health care and public health conditions across Europe and the rest of the World, and the health care systems could be organized in more clever and sustainable ways to exploit all the advantages of modern medicine. Furthermore, we need to face the accelerating challenges of environmental change (including climate change) with potentially significant impacts on both health and wellbeing and on our ecosystems and health care infrastructures.

Research is emerging rapidly in personalized medicine with a new approach to classify, understand, treat and prevent disease based on data and information on individual biological and environmental differences. The taxonomy of diseases is under revision, and we are moving away from a “one size fits all” approach towards health care tailored to the needs and characteristics of the individual. We need Europe to be in the driving seat of these developments, taking advantage of the innovative ICT revolution including ‘big data’. Society needs to take advantage of all the help available from new, smart and sustainable ICT solutions in both health and disease – for health care and for everyday life.

The European Commission is advised to do that through a coherent research programme with interdisciplinary, shared competences and convergence between research areas, including social science and humanities and science, technology and medicine. The programme needs to focus on the evidence-based use for new drugs and ICT solutions, and new algorithms for how to organize health care and public health.

The recommendations in this Advisory Group report were developed at the request of DG Research and Innovation, in reply to “Health, Demographic Change and Wellbeing”, which is Challenge 1 under the Horizon 2020 Research and Innovation Programme. Health care, health research and public health form a complex matrix that has many dimensions, and although the task is difficult, we recommend the following cohesive research programme described in clear, focused, short bullet points. The report is a collective effort with all authors being members of the Advisory Group.

Our eight main themes proposed with their potential strategic priorities in the report for the calls 2016–2017 are:

- 1) Ageing at large
- 2) Personalized medicine
- 3) ICT for health
- 4) Population health and health promotion
- 5) Infectious diseases
- 6) Early development
- 7) Sustainable health and care systems
- 8) Environment and health challenge

The overarching principles underlying all actions under the Horizon 2020 Societal Challenge 1, “Health, Demographic Change and Wellbeing” are:

Patients and citizens must be involved in the whole process, from the design of research programmes to the dissemination and implementation of results in health and social care, public health, and society. Tailoring of user-centred interfaces, decision supports and interventions based on user needs and capabilities are important, with investigation of models and community engagement to ensure inclusiveness, equity, relevance, and timeliness of efforts. Investigation is needed into the balance between personal contact and fully automated smart solutions.

Research integrity and ethics must be secured through Codes of Conduct leading to robust and valid data and respected throughout the whole research process. This is mandatory for all research themes. For big data, data security is even more complex, as it is important to ensure that it is possible to carry out research and at the same time maintain individual patient and citizen security. At the same time, access to data is essential for research and innovation purposes (while respecting individual data confidentiality).

The gender aspect must be addressed throughout the research programme. The researchers should be both males and females, in all areas and at all levels. For research subjects, the gender balance must also be considered: for animal studies, for studies in volunteers and for clinical studies patients of both sexes should be involved (where relevant). Research must be carried out along the whole life course from conception, early development, children, adolescents, through to adults, the ageing and the oldest old. It is not enough to focus research on young healthy males, neither for volunteers, patients or those who perform the research.

The group recommends focusing on quality in the design of programmes, calls and the peer review process with the use of “best practice” and an open, transparent methodology.

We recommend transnational collaboration with focus on the use of EU funds for research where Member States cannot solve the problems alone and where collaboration is needed. The programme needs to focus on international collaboration with researchers outside Europe,

and we need to focus on mobility of both young and senior researchers both across ERA and out of ERA and back again.

Medical research includes basic, translational and clinical research and implementation in clinical practice, with new research results considered to be proven by the principles of “evidence based medicine”. Medical research also includes public health and prevention. It is not a linear model, but a multidimensional model with a high level of complexity. The group recommends linking research to education and innovation and to use research results as basis for decision making.

Innovation is a broad concept that includes new products: drugs, diagnostics, tools, surgical procedures, software and hardware for imaging, medical technology and devices and a new, large area with ICT solutions and big data. ICT solutions will be relevant throughout the chain from prevention, screening, early diagnosis, treatment, rehabilitation and everyday life, including the growing number of patients with long-term, chronic diseases. The potential for industry and SME involvement is huge for all eight themes in this societal challenge area, not only for obvious new products, but also for new solutions and ways of organizing health and care. This will inevitably lead to new products not even thought of now.

Interdisciplinarity is crucial and links exist between all our eight themes. ICT can help to address challenges in all areas and personalized medicine may provide the underlying explanation for disease mechanisms in many research areas. In public health, the programme needs to focus on a holistic integration with other research areas. Both mental health and physical health influenced by physical health should be viewed in cohort studies, in interventions and with big data approaches. Tobacco, alcohol consumption, healthy food, healthy lifestyle with physical exercise and interactions with the natural environment with a sustainable approach to societal life should be the focus for the future. We need to re-think the future and let new, intelligent, sustainable, and if possible green sustainable approaches, provide the solutions to create better lives for our citizens.

Interdisciplinarity with regard to other scientific disciplines such as the life sciences, natural sciences, technical sciences, social sciences and humanities is crucial. Science building bridges between research areas and from research to patients, health care and societies. Science building bridges between nations in ERA and with the rest of the world. Science building bridges with industry. Health and healthy living is relevant to all the societal challenges. If the populations of Europe are healthy, happy, and thriving, Europe will be a better society and for all the other societal challenges we recommend that health and health care aspects are considered as integral. Finally, in a world of rapid environment changes that have potential impacts on health and wellbeing, “environment and sustainable solutions”, are overarching keywords of high importance for all research themes in this report and for the other societal challenges.

Conclusions

These are the recommendations from the Advisory Group for the potential strategic priorities for the work programme 2016/2017 and beyond for the Horizon 2020 Societal Challenge 1: “Health, Demographic Change and Wellbeing”.

Our main themes are: 1) Ageing, 2) Personalized medicine, 3) ICT for health, 4) Population health and health promotion, 5) Infectious diseases, 6) Early development, 7) Sustainable health and care systems, and 8) Environment and health challenge.

Recommendations will also come from the other Advisory Groups, from the Member States and Programme Committees, from conferences, workshops, lobbyists, the industry, the health care sector, researchers, patient organizations and society. The development of the programme is the result of a melting pot, where we all must strive to make the most out of scarce public research monies. We need research solutions to meet the challenges of tomorrow. The aim is to end up with a robust and impactful programme for the benefit of research, and thereby patients, health care, citizens and societies – in Europe and the rest of the world.

The cross-cutting issues of the Horizon 2020 Societal Challenges are key – with science building bridges between scientific disciplines, between science and society, and for health and health care with patients as the main focus and in the driving seat. Science building bridges between the ERA nations, and with nations in the rest of the world. Science building bridges with industry.

We recommend a focus on quality, with meritocracy and use of best practice in calls and the peer review process, and we underline the necessity of gender balance and high research integrity everywhere.

Health and healthy living are relevant to all the societal challenges. If the populations of Europe are healthy and thriving, Europe will be a better society and for all the other societal challenges we recommend that health and health care aspects are considered as crucial.

Forewords

Foreword of the chair and vice chair of the Advisory Group

We would like to thank the European Commission for a strong and visionary proposal for the Horizon 2020 Research and Innovation Programme. Allan Leschner, publisher of *Science*, was at the launch of the programme in 2012 in Copenhagen and called it “the most ambitious research programme ever seen on the planet”. It is our privilege and honour to be part of the Advisory Group for the Societal Challenge number 1: Health, Demographic Change and Wellbeing, and the Advisory Group members have made a great effort to compile the chapters of this report through small focused groups. As chair and co-chair, we would like to say “thank you for the great job done by our AG members”.

It has been a busy spring, as the Advisory Group only met for the first time late fall 2013. We were given the task of writing this report for the programme 2016/2017 early this spring 2014.

We would like to take the opportunity to thank the European Commission’s Directorates General “Research and Innovation” and “Connect” for their excellent collaboration and for their support in terms of information and professional sparring.

The societal challenges of the future are not to be seen as silos, wherein experts are isolated from each other in discrete academic disciplines. This Advisory Group needs to ensure collaboration and exchange of information with the AGs addressing the other societal challenges, and interaction in an interdisciplinary way is very important. That is one of the key messages of our Advisory Group.

Europe needs to find solutions for growth, prosperity and safety for the next decade in the area of health, demographic change and wellbeing. The challenges will be large and serious, and we need to collaborate to secure health, prosperity and the survival of our green and blue planet, the Earth.

Prof. Liselotte Højgaard
Chair
Brussels, July 2014

Dr. Rafael Bengoa
Co-chair

Foreword from the European Commission

The added value of research and innovation funded under Horizon 2020 is the scale and scope of co-operation between excellent teams, representing European and indeed global diversity. The same can be said of this Advisory Group, and we are indebted to them for their commitment to delivering such a high quality and thought-provoking document. We look forward very much to receiving the views of the broader stakeholder community, and to continuing to work with this Advisory Group, such that Societal Challenge 1 can deliver its promise of better health and quality of life for all.

This document is the first Advisory Group report for the 'Health, Demographic Change and Wellbeing' Societal Challenge of Horizon 2020. It provides an excellent starting point for deliberations on the next funding round of this challenge, the 2016/2017 work programme.

Ruxandra Draghia-Akli
European Commission
DG Research & Innovation
Brussels, July 2014

Paul Timmers
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<http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=2942>

1. Introduction and working method

This document provides the specific advice of the Horizon 2020 Advisory Group (AG) for Societal Challenge 1, “Health, Demographic Change and Wellbeing” towards defining potential priorities for EU research and innovation funding in the work programme 2016/2017.

The Commission services have been consulting this AG as a first step in the process towards preparing the next work programme. The consultation has been organized around meetings of the group taking place on 25 March and 18 June 2014.

The AG organized eight working groups, taking into account the different activities of the specific programme. The challenges and related working groups were identified in the AG meeting on 25 March 2014.

For consistency of the analyses of the challenges (see working group reports in Chapter 7) the groups used the same set of questions (see Annex 8.1, Chapter 8 of this document) based on the consultation paper provided by the Commission, (see Annex 3.2, Chapter 8).

All working groups made a SWOT (strengths, weaknesses, opportunities, threats) analysis for their challenge. The SWOT analysis is shown at the end of each section and a summarized analysis of all themes is presented after the working group reports.

2. The biggest research challenges requiring action under the work programme 2016/2017

- 1) Ageing at large
- 2) Personalized medicine
- 3) ICT for health
- 4) Population health and health promotion
- 5) Infectious diseases
- 6) Early development
- 7) Sustainable health and care systems
- 8) Environment and health challenge

1. Ageing at large

Understanding ageing and quantitative evaluation:

- Investigation of the underlying causes (e.g. molecular, physiological and physio-pathological, socio-economic) for the diversity in healthy life years across Europe, employing both subjective and objective indicators of health and wellbeing from longitudinal population studies.
- Research into behavioural and biological markers which could provide early signals of risk and/or deterioration and trigger intervention from longitudinal and cohort studies.

Conditions, diseases and co-morbidities in the oldest old:

- Analysis of and understanding diseases, especially in the oldest old in their ageing-specific dimensions.
- Screening of early manifestations of common geriatric syndromes in the oldest old.
- Treatment using personalized medical intervention in the oldest old.
- Understanding positive effects of active ageing and social inclusion.

Technological innovation:

- Research, development and piloting of tools and technological innovations (e.g. ICT, smart living environments, artificial and emotional intelligence, medical products, physical adaptations/devices, big data) that will enhance independence, social interaction, mobility, function and contribution to society, and quality of service provision.
- Investigation of methods to involve older and frailer people in research studies, with special attention to gender issues.

Research on health, social and environmental systems:

- Investigation of new systems of long-term sustainable health and care provision (building on e.g. communities, families, social services).
- Investigation of alternative economic models for projected need for sustainable health, social and pensions systems to better understand the societal benefits and strain of the ageing demographic. Comparison of best practices across different social and cultural contexts.
- Investigation of the barriers to accessing appropriate health and social care services among the older population.
- Research and analysis of expectations across Europe of younger generations for their future as older adults.
- Research to understand the long-term influence of childhood health on ageing.

2. Personalized medicine, mechanisms, system medicine, biomarkers and diagnostics

Personalized medicine should be demonstrated by applications in promotion of wellbeing, disease detection, prevention and treatment, aiming to demonstrate cost-effectiveness as well as health benefit and it should be accessible to diverse populations.

A more unified and systematic approach to the research and applications of personalized medicine is needed, for:

- Chronic multifactorial diseases affecting large sections of the population.
- Rare diseases, which affect very few persons individually but represent a significant societal challenge collectively.

The research should aim to establish or support a 'pipeline' needed to implement personalized medicine:

- Understanding diseases and their co-morbidities better at the systems and mechanistic levels. Formulating hypotheses for biomarkers or targeted interventions aimed at disease prevention or therapy.
- Development of tools for utilizing/extracting/sharing new knowledge in the most informative and efficient manner (e.g. molecular profiling, biotechnology, diagnostic, ICT tools) in the most appropriate personalized setting (e.g. health care system, at home). Accelerating and facilitating regulatory approval paths for new medical products for personalized medicine.
- Piloting the personalized medicine concept in real life settings (e.g. genetic/phenotypic screening programmes, responding to the paradigm shift in clinical trials which move away from unselected patient populations towards more individualized approaches in molecularly defined subgroups), demonstrating the health benefit and cost-effectiveness.
- Sharing the huge amounts of data generated in new and existing studies while ensuring confidentiality and data security, and feeding this information towards new discoveries (see above). Empowerment of the individual to manage his or her data.

An EU-wide approach to the utilization, maintenance and joining up of existing and future bio- and data-banks should be supported:

- There are many cohorts in Europe where individuals have been monitored and sampled over long periods of time, providing a wealth of health-related information which could now be comprehensively characterized with 'omics' technologies. By linking these studies with long term outcome data, they could become a "gold mine" for discoveries and innovation as well as for the validation of novel tools and solutions for personalized medicine.
- New studies should also be encouraged which collect/sample relevant medical information in longitudinal settings (health care system, workplace; also birth cohorts, natural history and epidemiological studies). Such studies will in time

gather crucial information for implementing and demonstrating the power of personalized medicine.

3. ICT for health

- Research is needed to establish the evidence for integration of ICT for health solutions in national health systems, building on current technological infrastructure through targeted applications and focused evaluation of these applications with long-term follow-up.
- This should also involve technological development and innovation to bridge the gap between raw technologies and business intelligence, amounting to a technologically enabled culture shift in health care and also in lifestyle promotion and wellbeing.

A dual focus is therefore needed:

- 1) Focus on **person-centred health care delivery**, also integrating health and social care and considering the environment and community setting of the individual.
- 2) A separate focus on **wellbeing and prevention** to identify trends towards ill health and so strive to keep people away from unnecessary care and to encourage them to be proactive.

4. Population health and health promotion

- We need to know more about the individual, social and political determinants of health. Knowledge about the determinants and the causal mechanisms are crucial for creating effective population-based and targeted interventions.

Focus on non-communicable diseases:

- Mental health disorders: Individuals with mental disorders, depression, anxiety, antisocial behavior, should be targeted and prioritized because mental illnesses contribute more to the global burden of disease in Europe than any other illnesses.
- Obesity is clearly another target. It carries with it all sorts of consequences and there is a lot of interest in whether these consequences are differentially related to obesity in childhood and middle adult age.
- Smoking among girls remains an issue and is hazardous for development and offspring.
- Illicit drug use and alcohol binge drinking cause concern.
- Social isolation among the elderly is common.

5. Infectious diseases at large

Vaccines:

- Research and development for vaccines against infections no longer controllable by antibiotics due to AMR, e.g., *S. aureus*, gonorrhoea, and for very specific severe emerging diseases.
- Vaccines for malaria (not part of the 2014–2015 programme).
- Research into new vaccine platforms and/or improvement of existing ones: for multi-antigen delivery; for more comprehensive protection against strain variation; for more rapid manufacture and scaling-up to respond to events or increased demand; for improved immunogenicity and/or safety; for immune-therapeutic interventions; for greater public acceptability.

Therapeutics including anti-infectives:

- Discovery and development of novel antibacterial agents to treat diseases such as tuberculosis and gonorrhoea, and to control infections with *Staph. aureus* and multi-drug-resistant Enterobacteriaceae.
- Antivirals against influenza, respiratory syncytial virus and herpesviruses (especially HSV and CMV).

Diagnostics and host–microbial interactions:

- Exploration of modalities for controlling sepsis through more comprehensive understanding of signalling pathways, both for diagnosis and for intervention.
- Development of affordable point of care (POC) and near-patient diagnostic tests for multiple agents and capable of enabling differential diagnoses.
- Research to reassess the position of biomarkers for diagnostics, assessment of stage of evolution of illness, to monitor treatments, to capture interactions between communicable diseases and NCDs and/or comorbidities as well as to guide choice of therapeutic interventions.

Clinical management for diverse resource settings:

- Development of new approaches to clinical trial design and of new regulatory pathways.

Improving standards to support innovation:

- Development of standards to support public acceptance of medicines and the manufacture and sale of safe and effective medicines, vaccines and health technologies.

6. Early development

- Discovery and delivery research of pathways and interventions can lead to optimal development, increase resilience and mitigate the impact of biological, psychosocial and environmental risk factors.

- A life course perspective is needed for addressing mental health and wellbeing from childhood to older ages. There is huge heterogeneity among children in their response to the same adversity, stress and trauma. Some children are more susceptible to both negative and positive influences. Consequently, we need research examining which protective processes and adaptive systems make a difference in children's lives and change the environment for the better. Variations in the expression of vulnerability for disorders across age and gender are striking. This has to be taken into consideration when designing prevention and implementing interventions.

7. Sustainable health and care systems

Policy research:

- Research on uptake of existing research evidence for policy-making and on policy bottlenecks, especially those concerned with quality and patient safety.
- Research on Human Resources for Health Policies (e.g. education, certification, recruitment, training, retention, migration).
- Research on how to move from a reactive health care system to implementing proactive and sustainable population health.

Implementation research:

- Systematic analysis and comparison, in various socio-economic and cultural contexts, of the most important determinants of effectiveness of health systems and of successful scaling up of innovations.
- Research on patient engagement and empowerment (e.g. health-seeking behaviour; individual patient and citizen satisfaction; attitudes and behaviours in m-Health and e-Health; training and use of new technologies; integration of civil society's needs in decision-making processes; measures of patient and health care provider satisfaction using qualitative and mixed-methods; changing relationships between health systems and professionals with patients, families and communities).
- Exploration of best practices towards creation of a continuous learning people-centred integrated health system including new value-based payment schemes and new leadership approaches.
- Research on the integration of health and social services, and community-based delivery systems, their impact on care, sustainability and new job profiles for the future.

Research on data management and technological change:

- Research on methods to analyse and interpret exponentially growing data sets.
- Research on approaches to enable the integration of big data in day-to-day health care management and delivery.

8. Environment and health

In the challenge area of environment and health, “environment” has been defined in both small and large terms, encompassing the individual human biome to the built and natural environments to local and global environmental change, including but not limited to climate change. The following are key research actions needed in environment and human health:

- Explore and measure the beneficial and negative impacts, as well as the underlying mechanisms and behaviours, arising from the interactions between the environment and human health and wellbeing, taking an inter/multi-disciplinary/institutional/sector approach with stakeholder engagement and attention to social equity.
- Expand the use of big data to include all types of data, with innovative data “mashups” of health and environmental data linkages (including longitudinal data from existing and new databases), for the purposes of: surveillance, screening, and identification of high risk populations and inequalities; the study of “mechanisms”; the modelling different approaches and scenarios; the creation of new methods; innovation; translation to policy makers and other stakeholders; etc.
- Promote innovation with technology to proactively change behaviour towards more sustainable lifestyles which promote both health and wellbeing and healthy ecosystems in a world of rapid environmental change; in this area, there is much to learn from developing countries.
- Provide concrete “motivational” examples at different levels (i.e. individual, familial, community, regional, national, international, and global) of successful behaviour change around prevention, adaptation, mitigation and resilience in the face of continual environmental change demonstrating impacts both on health and wellbeing and on ecosystems.
- Move towards sustainable health/public health/social care systems which would serve not only as important exemplars of best practice, but also as sources of innovation.

For a thorough description of each theme, please see Chapter 7.

3. Areas with the strongest potential for innovation and participation of industry and SMEs

For this Challenge, “Health, Demographic Change and Wellbeing”, which is Challenge 1 in Horizon 2020 Research and Innovation Programme, the possibilities for involvement of industry and SMEs are huge. All our eight themes have great innovative potential. Innovation is a broad concept comprising new products: drugs, diagnostics, tools, surgical procedures, software and hardware for imaging, medical technology and devices and a new, large area with ICT solutions and big data. ICT solutions will be relevant throughout the chain from prevention, screening, early diagnosis and treatment, through to rehabilitation and everyday life, including for the growing number of patients with long-term, chronic diseases.

Innovation also includes new procedures and new organizational approaches to health and health care and public health and prevention. Solutions here may secondarily imply innovative industry products. The themes where the innovative aspects are most prominent are probably those highlighted below. However, new breakthroughs may arise unexpectedly in any of the thematic areas, and may cause growth in various areas of the industry. In health care, biotech, medical technology and for the new area of personalized medicine, new drugs and diagnostics and other emerging products will strengthen the position and role of European SMEs.

- ICT and big data: patient-centred health care delivery and person-centred wellbeing and prevention delivery will be a huge area, where Europe can be at the forefront of innovation.
- Personalized medicine: new diagnostics, biomarkers, new drugs.
- Infectious diseases: vaccines, diagnostics, new drugs.

For a thorough description of each theme, please see Chapter 7.

4. Cross-cutting and interdisciplinary activities

Interdisciplinarity and collaborative research addressing the different societal challenges is important for Horizon 2020 to ensure that the research is used to its full potential. There are recommendations about inter- and cross-disciplinary research in all our eight research themes for Health, Demographic Change and Wellbeing, reaching out to the other Societal Challenges. The future organization of joint research activities should be developed in close collaboration with the Advisory Groups, and strong emphasis should be on quality, so that all partners in joint research projects are excellent. This can be implemented by a strong peer review system with focus on quality in all parts of the process. Focus on concrete proposals with practical forward looking solutions is crucial.

Patients and citizens must be involved in the whole process, from the design of research programmes to the implementation of results in health and care and society. Tailoring of user-centred interfaces, decision supports and interventions based on user needs and capabilities is important, together with investigation of models and forms of community engagement to ensure inclusiveness, relevance and timeliness of efforts. Investigation into the balance between personal contact and fully automated smart solutions is also important.

Interdisciplinarity or convergence between the themes mentioned in our report, and interdisciplinary engagement with other scientific disciplines such as life sciences, natural sciences, technical sciences, social sciences and humanities, are crucial. Science building bridges between research areas and from research to patients, health care and societies. Science building bridges between nations in ERA and with the rest of the world. Science building bridges with industry. Health and healthy living is relevant to all the Societal Challenges. If the populations of Europe are healthy, happy, and thriving, Europe will be a better society and for all the other Societal Challenges we recommend that health and health care aspects are considered. “Environment and sustainable solutions”, are overarching

keywords of high importance for all research themes in this report and for the other Societal Challenges.

Interdisciplinary is obvious between all our eight themes: ICT can help meet challenges in all areas and personalized medicine may provide the underlying explanation for disease mechanisms in many research areas. In public health the programme needs to focus on a holistic integration with other research areas. Both mental health and mental health influenced by physical health should be viewed in cohort studies, in interventions and with big data approaches. Tobacco, alcohol consumption, healthy food, healthy life style with physical exercise and a happy green environment with a sustainable approach to societal life should be the focus of the future. We need to re-think the future and let new, intelligent, sustainable, and if possible green approaches provide the solutions to create better lives for our citizens.

The gender aspect must be addressed throughout the research programme. The researchers should be both males and females in all areas and for all levels, from Masters and PhD students to professors. For research subjects the gender balance must also be ensured: for animal studies, studies in volunteers and clinical studies, patients of both sexes should be involved (where relevant). Research must be carried out along the whole life course from conception, early development, children, adolescents, to adults, the ageing and the oldest old. It is not enough to focus research on young healthy males, neither for volunteers, patients nor those who perform the research.

The group recommends focusing on quality in the design of programmes, calls and the peer review process with the use of “best practice” and an open, transparent methodology.

We recommend transnational collaboration with focus on the use of EU funds for research where Member States are unable to solve the problems alone, and where collaboration is needed. The programme needs to focus on international collaboration with researchers outside Europe, and we need to focus on mobility of both young and senior researchers across ERA and out of ERA and back again.

Medical research includes basic, translational and clinical research and implementation in clinical practice, if the new research results are proven by the principles of “evidence-based medicine”. Medical research also encompasses public health and prevention. It is not a linear model, but a multidimensional model with a high level of complexity. The group recommends linking research to education, innovation and to use research results as basis for decision making.

Cross-cutting key points for the organization of research:

- Patient, user and society involvement in all research steps from design of programmes and calls and organization of research to publication and implementation of results.
- Interdisciplinarity between our themes and convergence of scientific disciplines involving the other Societal Challenges.
- Transnational collaboration, within ERA and to the rest of the world, with focus on internationalization.
- Best practice in programme design, calls and peer review for applications.
- Inclusion of all age groups in research studies and protocols including children, elderly and the oldest old, where relevant.

- Alleviating the gender gap, for researchers and research subjects.

Cross-cutting for research content:

Environment and Health – focus on smart, sustainable green solutions for all societal challenges with the aim of improving health and wellbeing.

- Population health and health promotion – focus on strengthening the possibilities for healthy living on the life course from conception, throughout life and to old age, for lifestyle and use of person-centred deliveries.

5. Research ethics for data collection and management

Research integrity and ethics is a special cross-cutting area of utmost importance. It must be secured through Codes of Conduct leading to robust and valid data and respected through the whole research process. This is mandatory for all research themes – at any time, at any place. For big data and data security it is even more complex, and it is important to ensure that it is possible to carry out research and at the same time guarantee individual patient and citizen security.

Background

Longitudinal data sets, health registers and population-based data can be used for examining important societal research issues and individual health issues. Public health and population registries and other large databases derived from research can give answers to European demographic and health issues. When societies need new knowledge, access to registries and other large databases is paramount for researchers. High ethical awareness of the confidentiality of individual-sensitive data is essential for the trust of individual research participants, their families, health care providers, and communities. Research Ethics Committees seek to guarantee the confidentiality of sensitive personal data and to ensure low risks for participants in research studies. We recommend ensuring the highest standards of integrity in EU supported research, founded on the principles of good research practice, while maximizing the benefits to European citizens by generating the utmost advantage from extant and prospective databases and reducing the need for duplication of resources.

Challenges

Harmonization of regulations between countries is recommended:

Many countries in the EU have different research ethics regulations. Harmonization between countries will be of importance to facilitate ease of data exchange, decrease expense and work load, and improve citizens' trust in research.

Research involving humans is essential for biomedical and public health research; too many restrictions can hinder the use of vital data about individuals. Wherever possible, “broad” consents for research study participation should be encouraged, allowing the analysis of data in a variety of ways over time subject to the appropriate approval. The presence of such broad and written consent from individuals in many registries and other databases is not always available. This should not stop future research using these data if the purpose of the research

is of very high societal value and does not violate the confidentiality of the participants involved. We underline the importance of access by researchers to existing data banks and biobanks without having to ask the participants consent repeatedly. Such broad consent is possible in medical, psychological and social science research, while respecting participant/individual confidentiality.

Access to data not based on individual consents when the purpose of the research has high potential gain for society:

A balanced weight between “person sensitive” confidential issues on the one hand, and the expected impacts for larger society on the other, is necessary. While maintaining respect for individual autonomy, in cases when registry data are not solely based on individual consent, we suggest data could be made available for researchers if: the purpose is of high societal relevance and impact; where there will be minimal risks for the participants; and the study has been approved by an appropriate research ethics committee. This is particularly relevant for research that requires information about a whole population, special age groups or birth cohorts, or all patients receiving a particular type of treatment during a particular time period, which make registry data and other large databases very valuable.

Researchers should seek access to data in data banks and registries:

- When registries are the only relevant source for information for research.
- When failure to do so would stop the study from being conducted.

Researchers should do everything possible to prevent re-identification of a data subject:

Pseudonymization, irrevocable anonymization, and encryption are examples of methods that researchers can apply to protect confidential data (i.e. data which can potentially identify individual participants). The researcher is mandated to do whatever is needed to prevent any retrospective identification of study participants. Data files which merge the data of individual subjects and include personal identifying information should be stored securely, strictly away from other information. We need detailed guidelines on this issue for data of historical, statistical and research purposes that facilitate future research of high societal value; these guidelines could be incorporated into “broad consents” as a way of protecting future unspecified uses of the data at the time of initial consent.

Accessing data bases within the EU:

Potential problems:

- Ethical committee approval may be too narrow to allow post-hoc data sharing.
- Those controlling access to the data may not be willing to share it.
- Lack of knowledge and dissemination of existing longitudinal data resources leading to the loss of valuable resources.
- Lack of “linked” data from different existing data sources.

Possible solutions:

- Ensure that Research Ethics Committee approval permits the further use of the data in anonymized form for future studies and for meta analyses, including international

access and possible copying of the anonymized data outside the institution/country in which they were acquired as long as individual patient confidentiality is protected.

- For all EU-funded research ensure that there is a data access agreement in place as part of the contract between the researcher and the EU. This does not necessarily have to mean that all data are open access, but rather that the procedure for accessing them is defined. The expectation should however be to ultimately allow maximal access to the data compatible with retaining the anonymity of the subjects/patients.
- Encourage other funding agencies within Europe to implement similar schemes.

6. Opportunities for international cooperation

All working groups underlined the importance and necessity of collaborative research in Europe and beyond. In general, health issues are global but there is also a strong interest to keep Europe at the forefront of innovative developments in health research.

The complex challenges in health research cannot be dealt with by single researchers or single national groups. Depending on the area, this may include the need for further participants from all over the world to guarantee major achievements and innovation in the respective field. More specifically for some areas (2, 3, 7, 8) there is a strong need for collaboration with low- and middle-income countries (see below).

The group advises the Commission to continue but also to explore new avenues in international cooperation for new innovative solutions and the benefit of the patients and society at large. More specifically in the order of the areas, the group advises the Commission to support:

- *New flexible solutions for public, private, social, health and economic systems in Europe. The experience of creating these will provide the opportunity for Europe to offer global leadership and seize market opportunities in emerging economies. As a leader in ageing, Europe can advance public engagement to maximize the flow of ideas across society, rather than just within groups. By ensuring that public engagement is a component of all ageing-related activities, from research to the development of innovative technologies, Europe can break down barriers and cross-cut boundaries, ensuring a multi-disciplinary approach to problem-solving. Harmonization of longitudinal studies, for example, makes possible the development of an integrated framework across Europe and beyond with international and interdisciplinary collaborations to advance our understanding of ageing.*
- *International activities towards the piloting and implementation of personalized medicine. For example, in addition to developed countries, many developing countries face rapid increases in the incidence of diabetes and other chronic diseases (China, India, Mexico, for example). In addition to spreading the concept of personalized medicine to other health care systems, this could also open new business opportunities for EU companies.*
- *Learning from developing nations where ICT has been innovatively developed and applied to deal with existing constraints. Multilingualism, multicultural challenges, international laws and partnerships are global issues and need to be considered. Ethical issues around data confidentiality, IP, costs, and data ownership need to be explored and communicated.*

- *Combating NCD, promoting mental health and combating mental illness as this would reflect the recent understanding that these disorders contribute more to the global burden of disease in Europe than any other illnesses. There is a lack of integration between medical tradition, psychology and social sciences, which needs be addressed in Europe. Focus is still on medical initiatives (viz. WHO NCD Global Action Plan), excluding knowledge from psychology and social sciences.*
- *Broad and effective international collaboration for a comprehensive understanding of the behaviour and variation of the infectious agent, and the range of potential impacts in humans and animals. Diseases which have not yet appeared in a country may yet be introduced, and scientific preparedness for response and control must draw on the findings of research conducted in endemic regions. Collaborative research with an eye to affordable and durable solutions serves not only development objectives but, equally important, scientific and societal self-interest.*
- *Researchers from many countries to collaborate in examining early development from a global perspective (Gates, 2014; Masten, 2014). We need to understand better which resilience processes can be identified among children in low- or middle-income countries.*
- *Learning from both low- and middle-income settings about the use of participatory research methods that can play a major role in the development of indicators of patient satisfaction as well as ensuring sustainability through breaking down traditional barriers to access and equitable delivery of health and wellbeing.*
- *Learning from developing nations about adaptation and mitigation of environmental change. These countries have lived in resource-restricted environments with increasing pressures of rapid environmental change; they have examples of the application of innovative uses of new and existing technologies in resource-poor environments which can be adapted for use in the developed nations of the EU [UK Parliament Postnote ICT in Developing Countries, 2006].*

7. Thematic analyses

Outcome reports from working groups 1–8

7.1 Working group report: Ageing at large

WG leader	WG members
Rose Anne Kenny	Paolo Dario Marie-Paule Kiény Peter Saraga

What is the challenge?

Population ageing is a well-recognized demographic shift taking place at different rates across Europe. The European Union must recognize that this will require significant adaptation to ensure dignity and quality of life for all its members, in addition to health, economic and social resilience. Europe will gain immediate and long-term benefits by anticipating the necessary structural and societal adaptations required to ensure lasting social cohesion, economic vitality and population health across the ageing demographic.

The ageing research initiative should foster multidisciplinary research to address the most pressing problems of ageing and frailty by advancing approaches that integrate molecular, physiological, behavioural, economic, sociological, computational and technological studies, solutions and work that explores the ethical, social and philosophical questions raised by global population ageing, putting this to the forefront of the European research agenda.

Ageing is a complex mix of genetic, environmental, lifestyle and socioeconomic factors that influence lifespan, associated multimorbidity and rates of chronic diseases. Population ageing was initially driven by falling maternal and child mortality, followed by falling fertility rates. Now, the main driver is increasing longevity. Emigration of working-age adults continues to accelerate population ageing, as is observed now in many European nations.

The transition to older populations will challenge society in many ways. Demand for health care, long-term care, social services and pensions will increase, while the proportion of the population of traditional working age will fall. However, population ageing also presents many opportunities. Older people make important social contributions as family members, volunteers and active participants in the workforce. Indeed, older populations represent a substantial, but as of yet underutilized, human and social resource.

Furthermore, ensuring that the most vulnerable older people have access to the care and support they need is likely to have powerful benefits in terms of social cohesion, since all members of society will know these same resources will be available to them, as needed.

Rigid ideas about the life course and ageist stereotypes limit our ability to find innovative solutions and recognize the opportunities inherent in population ageing. For example, social systems often artificially categorize people into life stages based on chronological age (e.g. student, adult, retired). These concepts have little biological basis. With people living 10 or 20

years longer than previous generations, a range of life options, that would only rarely have been achievable in the past, now become possible.

Although health and social insurance expenditures are escalating and many countries estimate that these are not sustainable, there is emerging evidence that new economic models for projected need are required. The impact of population ageing on national economics is not only about strain on systems, but also relevant to societal benefits as new models of social entitlement programmes, labour market participation and trade opportunities are factored into traditional economic considerations, such as pension systems and care costs.

The wide diversity in lifespan and healthy life years, both within European countries and across countries, reflects a poor understanding of the factors driving variation in health outcomes and health inequalities in healthy ageing. Understanding the drivers (e.g. environment, genetics, socioeconomic position, health and social care system characteristics such as timely access to primary care, etc.) and their relationships to varied health and social care systems will help researchers to better address these challenges.

Barriers to accessing appropriate health and social care services are a real and ongoing challenge across Europe, and at present the role of different health and social care systems in exacerbating or alleviating such barriers to access is not well understood. In addition, there may be different barriers to access facing the older population, e.g. access to transport, information, and so forth.

New research on communications, electronics and artificial intelligence will have a significant impact on the lives of older persons, for example, in enhancing independence, social interaction, mobility, function, care and the provision of services such as e-health. Technologies and environmental developments should be accessible, inclusive and relevant for and to an ageing population, who may be frail or non-tech savvy; and include robust ideas such as multi-modal transport, technology-enhanced community engagement, and smart solutions which involve user-centred design and application. The rapid increase of “smart” solutions is designed around constantly changing technologies, social networking and cultural shifts. Such a rate of change is bewildering to the older population and the less technologically savvy and their needs are often not catered for in the race for the latest technology uptake.

The speed of demographic ageing is also varied and diverse. The same demographic ageing process that unfolded over more than a century in France will occur in a few decades in some Eastern European countries and major global emerging economies such as China and Brazil. In response to this “compression of ageing,” institutions must adapt quickly to accommodate a new age structure. Because Western Europe has more experience of the ageing process, the EU has a significant advantage in developing and modelling best practices that others may learn from.

If Europe acts now, there are exciting opportunities for societal transformation and long-term sustainability, in addition to economic benefits from the provision of new products and services. The window of opportunity is imminent as other countries prepare for accelerated ageing. Europe must act to capitalize on fiscal opportunities driven by global ageing; the cost of waiting – both social and financial – will be overwhelming.

Research has a critical role in meeting these challenges, by delivering solutions that are appropriate to cultural, social and economic contexts, in particular for the oldest old, most vulnerable and frail members of our society, who have largely been excluded from decision-making processes thus far. This, too, represents another opportunity: to advance programmes around ageing which are inclusive and engaging if we are to effect lasting change.

Why is this a challenge?

The individual: the ageing process

We know little of the underlying pathophysiology of ageing and in particular of the oldest old. We understand little of the drivers of frailty or resilience, or how these can be harnessed for research purposes. The causes of many of the disorders and/or diseases which characterize ageing such as frailty, dementia, cardiovascular disease, falls, multimorbidity and disability, are poorly understood.

A better understanding of the multiple factors that contribute to extended lifespan and age-related disorders, and their interactions, and how best to integrate research at many levels (molecular and cellular, tissue and organ, system and whole-organism, individual, and population, together with integration of new models of service delivery, policy change and environmental design) is required. The challenge is to apply this new knowledge and consequent innovations to prevent, diagnose and treat diseases and disorders in the old and oldest old, and to provide an evidence base to inform public health and social policy, while taking into account the cultural, social and health care settings which maximize dignity, quality of life and independence.

Society: the ageing process

Current European health, social care and pension systems are fragmented and not sustainable. Existing systems are not constructed in a manner that will adequately meet the needs of this changing demographic. Additionally, current funding structures are unsustainable. There are huge opportunities for new and more flexible solutions for public, private, social, health and economic systems in Europe. There is potential to foster greater efficiency in the provision of health, social and pension systems, via greater use of IT, generic drugs, reform of provider payment methods and the increased use of health technology assessment. The experience of creating new and innovative solutions towards ensuring the sustainability of health, social and pension systems will offer the chance for Europe to provide global leadership and seize market opportunities in emerging economies through tried and true advancements.

Towards the end of life, many people will require assistance beyond that habitually needed by a healthy adult. Most individuals in this situation prefer this “long-term care” to be provided in their home, and family members often deliver this. For those with severe functional decline, institutional care may be required. There are few standards or guidelines on the most appropriate care, and family carers often lack an understanding of the challenges they face as they are disconnected from health services. This can leave the needs of the older person inadequately addressed, with carers facing a greater burden than is necessary, while acute care services are inappropriately used to fill gaps in chronic care. Furthermore, ongoing changing social patterns (such as smaller family sizes, increased female labour force participation, greater labour mobility, and so forth) may mean that it will not be feasible to rely solely on families alone to meet many of these needs. The relative number of older family members is dramatically increasing, at a time when older people are less likely to live with younger generations and are more likely to express a desire to continue living in their own home. Women, the traditional family carers, may have changing career expectations that conflict with becoming daily care providers. New systems of long-term care are, therefore, urgently required to provide a continuum of care that is tailored to a continuum of need. These should be focused on the individual, closely linked to health systems, and designed to maintain the best possible function, wellbeing and social engagement. These are not problems that can wait

for future action – even today, our systems do not adequately meet these needs, and as populations age, the gap will become even more obvious and severe.

Multiple agencies: the ageing process

Multiple agencies are involved in health, social care and environmental systems. No single agency is responsible for development and implementation of policy and practice across the citizen's lifespan. Consequently, services are fragmented, often wasteful and inefficient, and the needs of older people and their careers are not appropriately realized. The challenge is to better understand existing service models and to respond to system inadequacies with innovative, more efficient and cost-effective systems.

Ageism

There is significant lack of awareness of ageing issues and the ageing process amongst practitioners, researchers, policy makers and the general public. Researchers and policy makers are not sufficiently aware of the needs or abilities of older people. Therefore, there is a requirement to better educate and train professionals, researchers, policy makers, patients and carers in ageing. This will ensure that informed decision-making around ageing is taken account of when developing new technologies, new systems and better environments (such as smart cities). Many educational institutions provide inadequate training on age-related issues despite the fact that many students will spend a significant proportion of their professional lives working with older people. Socially and culturally, the effects of ageism are vast – ranging from invisibility for older persons to negative stereotypes and discriminatory practices.

The oldest old are often excluded from clinical trials

Due to ethical issues, complexity of inclusion, monitoring and multimorbidity, vulnerable and disadvantaged populations are often excluded from clinical trials. The challenge is to investigate systems so that we may involve older and frailer participants in research.

Competition from emerging global cultures

Population ageing is a global challenge. Countries that maximize the opportunity and minimize the cost of ageing will have a competitive advantage over countries which do not. Given that Europe is ageing more rapidly than many middle-income and developing countries, there is an opportunity for Europe to provide leadership and for the public and private sectors in Europe to play a pivotal role in this leadership initiative and to capitalize on the European demographic experience. If Europe fails to take a lead on this initiative, other countries will, and this opportunity will be lost. In addition to improving quality of life and improving health and the health economic status of Europe, there are huge commercial opportunities, if advanced in a timely manner.

Action/research needed

Immediate research priorities for the 2016–2017 period include:

Understanding ageing and quantitative evaluation

- Investigation of the underlying causes (e.g. molecular, physiological and physio-pathological, socio-economic) for the diversity in healthy life years across Europe, employing both subjective and objective indicators of health and wellbeing from longitudinal population studies.
- Research into behavioural and biological markers which could provide early signals of risk and/or deterioration and trigger intervention from longitudinal and cohort studies.

Conditions, diseases and co-morbidities in the oldest old

- Analysis and understanding of diseases, especially in the oldest old in their ageing-specific dimensions.
- Screening of early manifestations of common geriatric syndromes in the oldest old.
- Treatment using personalized medical intervention in the oldest old.
- Understanding positive effects of active ageing and social inclusion.

Technological innovation

- Research, development and piloting of tools and technological innovations (e.g. ICT, smart living environments, artificial and emotional intelligence, medical products, physical adaptations/devices, big data) that will enhance independence, social interaction, mobility, function and contribution to society, and quality of service provision.
- Investigation of methods to involve older and frailer people in research studies, with special attention to gender issues.

Research on health, social and environmental systems

- Investigation of new systems of long-term sustainable health and care provision (building on, for example, communities, families, social services).
- Investigation of alternative economic models for projected need for sustainable health, social and pensions systems – to better understand the societal benefits and strain of the ageing demographic. Comparison of best practices across different social and cultural contexts.
- Investigation of the barriers to accessing appropriate health and social care services among the older population.
- Research and analysis of expectations across Europe among younger generations for their future as older adults.
- Research to understand the long-term influence of childhood health on ageing.

The following principles should underlie all actions under the Horizon 2020 Ageing theme:

- Involvement and engagement of all stakeholders in research including the older population and carers.
- Tailoring of user-centred interfaces, decision supports and interventions based on user needs and capabilities.
- Investigation of models and forms of community engagement to ensure inclusiveness, relevance and timeliness of efforts.
- Investigation into the balance between personal contact and fully automated smart solutions.

Innovation needed in relation to the challenge

Action

- New health and social care and pensions systems which provide optimal outcomes for older people, societies and economies.
- Technologies to enable mobility and independence, prevent falls, disability and frailty.
- Better built-environments to support older people and encourage retained function and active engagement, including new and adaptive models for service provision both within in and outside the home.
- New biomarkers of ageing in the oldest old and application of new technologies and treatments in this cohort.

Products

- New drugs and modifications of extant drugs tailored for frail older people.
- Novel and extended smart ICT solutions to ensure accessibility, independence and inclusiveness.
- New modes of engagement to ensure inclusiveness and co-design in processes.
- New social science models for active living in a smart cities.
- New and adaptive models for evaluating service provision at local, regional and state levels for relevance to ageing populations.
- New and adapted medical devices tailored for frail older people.
- New models of service delivery, ensuring autonomy, inclusion, cost efficiency and independence.

Success criteria

- New biomarkers for ageing, in addition to discoveries of the causes of age-related diseases such as dementia, stroke, frailty.
- New products, services and drugs tailored to the oldest old, with new service models and technologies for screening, early detection and prevention of frailty, degenerative brain diseases, and disability.

- New job opportunities in service delivery and technology development within the labour market and participation of older populations through modifications of working environments to enable inclusion of older workers.
- Health care and public health models which are affordable and cohesive.

The success criteria for health care and public health should be relative to the satisfaction levels of the target community, measured using standard elicitation techniques. Addressing the challenges will require significant multidisciplinary cooperation, which should result in innovations in research and technology, generating top-quality publications and innovative products. The inclusion of industry partners in the research should also result in outputs measurable in terms of economic growth.

Internationalization and collaboration

Huge opportunities exist for new flexible solutions for public, private, social, health and economic systems in Europe. The experience of creating these will provide the opportunity for Europe to offer global leadership and seize market opportunities in emerging economies. As a leader in ageing, Europe can advance public engagement to maximize the flow of ideas across society, rather than just within groups. By ensuring that public engagement is a component of all ageing-related activities, from research to the development of innovative technologies, Europe can break down barriers and cut across boundaries, ensuring a multi-disciplinary approach to problem-solving. The goal should be to enrich and broaden thinking, refine ideas and ensure relevance through coalition-building efforts. Additionally, engagement across Europe deepens social cohesion and the development of a healthy civic identity, while providing platforms for evaluating the impact of research across populations. Harmonization of longitudinal studies, for example, makes possible the development of an integrated framework across Europe with interdisciplinary collaborations to advance our understanding of ageing.

Bottlenecks

Where are the bottlenecks?

The bottlenecks are evident in four settings/levels – Policy, Cost, Systems, Information/Research Experience:

- Policy – There are multiple agencies involved and no single agency, at present, can take responsibility alone for coordinating services to support healthy, successful ageing; policy makers lack an understanding of ageing processes and cannot ensure seamlessness in the provision of services across agencies. This applies at regional, national and European levels.
- Cost – To date, inadequate resources from governments exist for longitudinal data collection, though governments rely on the data generated to assess policies, recommendations, behaviours, and needs.
- Systems – Across Europe, diverse health and social care systems exist; such fragmented health and social care systems within countries results in duplication, inefficiencies and the unequitable provision of services.
- Information/Research Experience – Acknowledgement of the scale and critical mass of researchers in ageing is needed. Many countries have inadequate training for

professionals in ageing, despite that fact that most of these professionals are involved in care of the elderly. Clinical leadership is fragmented and diverse; some EU countries have inadequate clinicians trained in medical gerontology. There are also inadequate numbers of academic clinicians to provide leadership compared with other specialties such as oncology, respiratory disease, cardiovascular medicine and diabetes.

How can the bottlenecks be alleviated?

- Research that informs a better understanding of ageing processes (e.g. immunity, inflammageing and nutrition).
- Integrated research from basic sciences and social sciences through to clinical and practice settings, policy implementation and the environment.
- Inclusion and engagement of “users” including the oldest old, frail older people and cognitively impaired older citizens in research studies and clinical trials.
- Single government agencies responsible for coordination of age-related research, policy change and implementation.
- Government support and resource allocation for longitudinal data collection.
- Harmonized data in each European country in social, health, economic and environmental domains, including objective and subjective measures of health.
- New and expanded systems to include comprehensive training in medical gerontology for medical, nursing, and other health care professionals.
- Training programmes for policy makers and researchers engaged in technology and drug innovations.
- Funding for mining longitudinal data sets, harmonizing research across populations and advising policy makers on lessons learned.

Risks

What are the risks?

- **Timeliness** – Failure to address the ageing issues in the next calls of H2020 will allow competing economies to take a competitive advantage and Europe will lose its potential leadership role and market share. Additionally, the lack of preparedness for the impacts of population ageing will negatively affect all populations through unsustainable economies, overloaded agencies, and financially strained health care services.

How can these risks be minimized or avoided?

- **Act now** – A concerted effort is required to address the challenges and to advance towards the goals for service provision. Accessibility, inclusiveness and relevance of technologies for the older population must be better understood. There is a risk that the right mix of multi-disciplinary focus will not sufficiently engage or advance a solution that caters to ageing needs without greater coordination and harmonization of efforts. Investing in longitudinal studies advances informed decision-making and allows for studying the impacts of decisions over time, coupled with the impact of natural experiments. We must rely on more than an anecdotal understanding of ageing if Europe is to advance leadership in this area.

Gaps

Where are the gaps?

- Lack of comparable longitudinal data from studies of ageing incorporating comprehensive health, social, economic and environmental information.
- Lack of accurate economic forecasts and impact of policies on vulnerable populations.
- Lack of awareness of the ageing process and ageing issues amongst researchers developing technologies for ageing.
- Inadequate numbers of frail older participants in cohort studies and clinical trials.

How can the gaps be closed?

- Fund longitudinal data collection and the harmonization of data across studies.
- Ensure Open Access of data sets.
- Build capacity for analyses of big data and longitudinal data to ensure informed decision-making.
- Build capacity in medical gerontology and academic gerontology.
- Research trials focused on older frail patients.
- Inclusion of frail older adults in research trials.
- Consideration of “users” such as frail older citizens in all H2020 SWOT reports.
- Investigate how to make smart cities accessible, inclusive and relevant to ageing.
- Include public engagement in H2020 efforts to advance project, programme and policy impacts.

Game changers

What are the game changers that would significantly help to meet this challenge?

- Leadership by a single agency at the policy level with responsibility for ageing and coordination of cross-agency collaboration in each European country.

- Education and training on ageing for doctors, nurses, pharmacists, physiotherapists, the private sector, and the public sector.
- Inclusion of ageing in all research programmes unless an explicit reason for exclusion is deemed necessary.
- Each European country should fund the collection of comprehensive population datasets on ageing to ensure informed decision-making and harmonization of data across countries. Without such foundational information, inequitable and unsustainable service provisions will continue, overloading national and European systems.

How to develop and implement these game changers

- Create an Office of Older Persons or Ministry for Ageing in each European country.
- Member States should provide financial support for the collection of longitudinal datasets to inform research and policy and to evaluate impacts of policy changes on populations. This is the most efficient way to ensure government responsiveness and acknowledgement of policy impacts.

Horizon 2020 aims at developing new knowledge and innovative products and services, creating growth and jobs in Europe, through:

- Mobilizing resources to build scale and critical mass for ageing researchers across Europe.
- Exploiting well-developed research and innovation agendas already in existence.
- Securing world class scientific and innovative breakthroughs in ageing.
- Advancing useful, timely technologies.
- Promoting ongoing dialogue between researchers and the public in order to determine the biological, social and environmental components of healthy ageing.
- Empowering a scientifically literate population who can advocate for their own health and wellbeing.
- Advancing technologies to improve economic, social and health indicators for older adults.
- Raising awareness of research findings and innovative technologies amongst doctors, nurses, social workers and other front line care providers to ensure accurate diagnoses and effective treatments.
- Combating ageism through diverse models of healthy ageing across the life-span.
- Celebrating the contributions that older people make to society and facilitate knowledge transfer between generations.
- Inspiring future generations of researchers in ageing.

Role of the public sector

What is the public sector's role?

There are multiple agencies involved with ageing. However, at present, no single agency can take responsibility alone for coordinating services to support healthy, successful ageing. Policy makers lack an understanding of ageing processes and cannot ensure seamlessness in the provision of services across agencies; this applies at regional, national and European levels. There are huge opportunities for new and more flexible solutions for social, health and economic policies in Europe. Ultimately, policy-makers working alongside researchers to establish and prioritize needs allows for responsive and effective governments.

How should this role best be implemented?

- A single government agency responsible for coordination of age-related research, policy change and implementation.
- Government support and resource allocation for harmonized longitudinal data collection.
- Training programmes for policy makers and researchers engaged in technology and drug innovations.
- Researchers involved in development and implementation of policy.
- Accurate economic forecasts and impact of the policies on vulnerable populations by researchers.
- Researchers involved in developing and vetting technologies for ageing.
- Engagement of frail older participants in cohort studies and clinical trials, with outcomes presented to policy-makers.
- Research Committee appointed to government which advises both the production of future research, policy reviews and needs assessments across target populations.

Strong areas for industry and SMEs

While the current market in this area is still very limited, it is clear that addressing these challenges will create major business opportunities, and many companies are engaged – some of whom are members of an alliance that has produced roadmaps.

The imminence of significant growth in the potential market means that the market may well experience rapid growth in the next ten years. If Europe is to take advantage of this growth, it is critical that we invest in underlying research and innovation in the areas of smart cities, innovative technologies, sustainable health care service provision, insurance, pharmaceuticals and new biomarkers for personalized medicine.

There is massive industry interest and focus on smart cities. It is anticipated that by 2020, the smart city technology market will be worth \$20.2 billion annually, compared to \$6.1 billion in 2012. Most of the major ICT MNCs, and a growing number of SMEs and start-ups, focus on “smart” solutions to some aspect of a smart city.

Strong areas to support integrated activities for each of the big challenges

Social science and humanities

Research into addressing the challenges related to making the macro-environment accessible, inclusive and relevant for an ageing population will not be successful without a strong multidisciplinary focus, where health scientists, computer scientists, engineers, urban planners, and social scientists work together to engage stakeholders and co-design appropriate solutions. The economic costs and economic opportunities afforded by the ageing demographic should underpin all activities, recognizing that solutions will have much wider applications for a cohesive society for all.

Responsible research and innovation, including gender aspects

Ethical issues are particularly pertinent to vulnerable, frail and cognitively impaired older persons. H2020 should inform the debate in Parliament, with an emphasis on data access, since this will impact on the harmonization of datasets which are essential for policy development. Such use of big data is also required for innovation in technology, treatments and policies.

Gender differences are particularly pertinent to ageing, for example:

- Women outlive men.
- Loneliness and social isolation is common in single women.
- Women provide most of the informal care.
- Women represent the ‘sandwich generation’.
- Women are more subject to pension poverty and financial insecurity.
- Women experience different age-related health problems, with frailty and falls more common in women.
- On the other hand depression is more common and longer lived in widowers than widows, and poor nutrition and cardiovascular disorders are more common in men.

Climate and sustainable development

The World Health Organization has noted that providing care for older persons during emergency situations is complex. The needs of older people are often overlooked by governments and humanitarian organizations in terms of policy and practice. There are specific health and social factors that impact older persons during an emergency situation. These include:

- Physical health
- Mental health
- Functional status and disability
- Lifestyle habits
- Nutrition

- Family and social relations
- Economic situation
- Gender considerations

Longitudinal data sets can provide a clearer understanding of levels of need and preparedness in older populations.

In terms of sustainable development, efforts to advance quality care environments – both at home and through public/private care facilities – for persons with degenerative brain diseases are an urgent need. The World Health Organization’s report on dementia, *Dementia: A Public Health Priority*, underscores the urgency. Key messages from the report include:

- Dementia is not a normal part of ageing.
- 35.6 million people were estimated to be living with dementia in 2010. There are 7.7 million new cases of dementia each year, implying that there is a new case of dementia somewhere in the world every four seconds. The accelerating rates of dementia are a cause for immediate action, especially in low- and middle-income countries where resources are few.
- The huge cost of the disease will challenge health systems to deal with the predicted future increase of prevalence. The costs are estimated at US\$604 billion per year at present and are set to increase even more quickly than the prevalence.
- People live for many years after the onset of symptoms of dementia. With appropriate support, many can and should be enabled to continue to engage and contribute within society and have a good quality of life.
- Dementia is overwhelming for the caregivers and adequate support is required for them from the health, social, financial and legal systems.
- Countries must include dementia on their public health agendas. Sustained action and coordination is required across multiple levels and with all stakeholders – at international, national, regional and local levels.
- People with dementia and their caregivers often have unique insights to their condition and life. They should be involved in formulating the policies, plans, laws and services that relate to them.
- The time to act is now by:
 - promoting a dementia-friendly society globally
 - making dementia a national public health and social care priority worldwide
 - improving public and professional attitudes to, and understanding of, dementia
 - investing in health and social systems to improve care and services for people with dementia and their caregivers
 - increasing the priority given to dementia in the public health research agenda

The definition of sustainable development should include accommodation of persons across the lifespan. Longitudinal data sets provide current and historical information on how people live, needs across the lifespan, and circumstances that allow for independent living versus those that necessitate assisted living or palliative care.

SWOT analysis

<p>Strengths</p> <p>Widespread government interest to adapt to demographic change.</p> <p>Societal expectations that ageing should be healthy. Research and development of new models, products and applications are often sought and welcomed.</p> <p>Some knowledge exists, especially in countries already affected by the demographic revolution (e.g. Japan)</p>	<p>Weaknesses</p> <p>Current knowledge limited in scope and depth, little implementation science, ageist stereotypes lead research to outdated solutions.</p> <p>Poor understanding of fundamental ageing process and drivers of frailty and dependency.</p> <p>Inadequate research in older frailer cohorts.</p> <p>Lots of pilots but not enough investment in scaling up and evaluation. Absence of coordinated and coherent application of research outcomes.</p> <p>Cross-sectoral collaboration as a routine is still not the norm.</p> <p>Lack of comparable harmonized information across countries to better understand risk factors and best practice and policy.</p> <p>Inadequate collection of large longitudinal datasets for cross-country comparison of objective and subjective measure of health and other relevant information.</p>
<p>Opportunities</p> <p>New appreciation of the importance of ageing in health and development for countries of all levels of development.</p> <p>Industry/SMEs/academia collaboration, in and beyond the health sector to develop older-people-friendly and older-people-centred health technologies – including assistive devices – and ICT applications.</p> <p>Well-developed models of cross disciplinary longitudinal data collection which can be replicated across cultures.</p> <p>Significant opportunities to develop better service delivery and integration models for countries at all levels of development.</p>	<p>Threats</p> <p>Ageing perceived as a cost only to that section of society.</p> <p>Solutions led by technology rather than by patient-centred needs.</p> <p>New proposed EU legislation restricting scientific exploration of extant data sets.</p>

Key references

- Mosca, I., Bhuachalla, B. N. & Kenny, R. A. (2013). Explaining significant differences in subjective and objective measures of cardiovascular health: evidence for the socioeconomic gradient in a population-based study. *BMC Cardiovascular Disorders*, **13**, 64.
- Theou, O., Brothers, T. D., Peña, F. G., Mitnitski, A. & Rockwood, K. (2014). Identifying Common Characteristics of Frailty Across Seven Scales. *Journal of the American Geriatrics Society*, **62**(5), 901–906.
- Kowal, P., Chatterji, S., Naidoo, N., Biritwum, R., Fan, W., Ridaura, R. L. & Boerma, J. T. (2012). Data resource profile: the World Health Organization Study on global AGEing and adult health (SAGE). *International journal of epidemiology*, **41**(6), 1639–1649.
- Global health and aging*. World Health Organization, 2011.
- Cruz-Jentoft, A. J. & Gutiérrez, B. (2010). Upper age limits in studies submitted to a research ethics committee. *Aging clinical and experimental research*, **22**(2), 175–178.
- Aapro, M. S., Köhne, C. H., Cohen, H. J. & Extermann, M. (2005). Never too old? Age should not be a barrier to enrolment in cancer clinical trials. *The Oncologist*, **10**(3), 198–204.
- Walker, A. & Maltby, T. (2012). Active ageing: a strategic policy solution to demographic ageing in the European Union. *International Journal of Social Welfare*, **21**(s1), S117–S130.
- Bech, M., Christiansen, T., Khoman, E., Lauridsen, J. & Weale, M. (2011). Ageing and health care expenditure in EU-15. *The European Journal of Health Economics*, **12**(5), 469–478.
- Abrams, D., Russell, P. S., Vauclair, M. & Swift, H. S. (2011). Ageism in Europe: Findings from the European Social Survey.
- Silcock, D. & Sinclair, D. (2012). *The cost of our ageing society*. ILC-UK.
- Beard, J., Biggs, S., Bloom, D. E., Fried, L. P., Hogan, P. R., Kalache, A. & Olshansky, S. J. (2012). *Global population ageing: peril or promise?* (No. 8912). Program on the Global Demography of Aging.
- Collard, R. M., Boter, H., Schoevers, R. A. & Oude Voshaar, R. C. (2012). Prevalence of Frailty in Community-Dwelling Older Persons: A Systematic Review. *Journal of the American Geriatrics Society*, **60**(8), 1487–1492.
- Radl, J. (2012). Too old to work, or too young to retire? The pervasiveness of age norms in Western Europe. *Work, Employment & Society*, **26**(5), 755–771.
- Crome, P., Lally, F., Cherubini, A., Oristrell, J., Beswick, A. D., Clarfield, A. M. & Mills, G. (2011). Exclusion of Older People from Clinical Trials. *Drugs & Aging*, **28**(8), 667–677.
- Aapro, M. S., Köhne, C. H., Cohen, H. J., & Extermann, M. (2005). Never too old? Age should not be a barrier to enrollment in cancer clinical trials. *The Oncologist*, **10**(3), 198–204.
- Yang, Z., Slavin, M. J. & Sachdev, P. S. (2013). Dementia in the oldest old. *Nature Reviews Neurology*, **9**(7), 382–393.
- Tuljapurkar, S., Li, N. & Boe, C. (2000). A universal pattern of mortality decline in the G7 countries. *Nature*, **405**(6788), 789–792.
- van Houwelingen, Anne H., Ian D. Cameron, Jacobijn Gussekloo, Hein Putter, Susan Kurrle, Anton JM de Craen, Andrea B. Maier, Wendy PJ den Elzen, and Jeanet W. Blom. (2014). "Disability transitions in the oldest old in the general population. The Leiden 85-plus study." *Age* **36**, no. 1, 483–493.
- Beck, B. (2009). A slow burning fuse: A special report on aging populations. *Economist*. June 25.
- <http://www.who.int/ageing/emergencies/en/>
- <http://www.alz.co.uk/WHO-dementia-report>
- Cf report by Technolage (<http://www.aal-europe.eu/technolage-final-study/>)

7.2 Working group report: Personalized medicine, mechanisms, systems medicine, biomarkers, diagnostics

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Executive summary

Personalized medicine should be demonstrated by applications in the promotion of well-being, disease detection, prevention and treatment; it should aim to demonstrate cost-effectiveness as well as health benefit and it should be accessible to diverse populations.

A more unified and systematic approach to the research and applications of personalized medicine is needed for:

- Chronic multifactorial diseases affecting large sections of the population.
- Rare diseases, which affect very few persons individually but represent a significant societal challenge collectively.

The research should aim to establish or support a ‘pipeline’ needed to implement personalized medicine:

- A better understanding of diseases and their co-morbidities as well as resilience to disease at the systems and mechanistic levels. Formulating hypotheses for biomarkers or targeted interventions aimed at disease prevention or therapy.
- Development of tools for utilizing/extracting/sharing new knowledge in the most informative and efficient manner (e.g. molecular profiling, biotechnology, diagnostics, ICT tools) in the most appropriate personalized setting (e.g. health care system, at home). Accelerating and facilitating regulatory approval paths for new medical products for personalized medicine.
- Piloting the personalized medicine concept in real life settings (e.g. genetic/phenotypic screening programmes, responding to the paradigm shift in clinical trials which move away from unselected patient populations towards more individualized approaches in molecularly defined subgroups), demonstrating the health benefit and cost-effectiveness.
- Sharing the huge amounts of data generated in new and existing studies, while ensuring confidentiality and data security, and feeding this information towards the new discoveries (see above). Empowerment of individuals to manage their data.

An EU-wide approach to the utilization, maintenance and joining up of existing and future bio- and data-banks should be supported:

- There are many cohorts in Europe where individuals have been monitored and sampled over long periods of time, producing a wealth of health-related information

which could now be comprehensively characterized with ‘omics’ technologies. By linking these studies with long-term outcome data, they could become a “gold mine” for discoveries and innovation as well as for the validation of novel tools and solutions for personalized medicine.

- New studies should also be encouraged which collect/sample the relevant medical information in longitudinal settings (health care system, workplace; also birth cohorts, natural history and epidemiological studies). Such studies will in time gather crucial information for implementing and demonstrating the power of personalized medicine.

What is the challenge?

Personalised medicine refers to a medical model using characterization of individuals’ phenotypes and genotypes (e.g. molecular profiling, medical imaging) for tailoring the right therapeutic strategy for the right person at the right time, and/or to determine the predisposition to disease and/or to deliver timely and targeted prevention.

The challenge of “personalized medicine, mechanisms, systems medicine, biomarkers, diagnostics” is to generate and translate new knowledge gathered in biomedical/health research towards the implementation of personalized medicine in health care, public health and social service settings.

The challenge addresses the key levels of personalized medicine. These include generating new disease knowledge at the systems as well as mechanistic levels; understanding disease co-morbidities; developing tools for implementing personalized medicine in an affordable manner; piloting and demonstrating the benefit of personalized medicine approaches in real life setting; and engaging patients in the management of "their" health and disease. For example, new research strategies such as systems approaches are needed to integrate the individuals’ data and their variation in time, and to utilize this information in the context of disease models. New tools (e.g. diagnostic, ICT) are needed for early disease detection and prevention, and for tailoring the appropriate therapy for each individual. Furthermore, personalized medicine requires the engagement of individuals (healthy, patients) and their health care professionals as well as of the health care and public health systems.

Why is this a challenge?

Due to increasing costs of non-communicable diseases, the pressure on European health care systems is rising. The ‘omics’ technologies allow for comprehensive characterization of individual phenotypes and genotypes, providing an opportunity for both identifying the risk of disease early and for tailoring the interventions for disease prevention or treatment. Advances in biotechnology are also opening new avenues for disease prevention and therapyⁱ.

Research is also needed in order to make the best use of ‘omics’ data, and to utilize it in personalized setting (i.e. the statistical associations of ‘omics’ data with disease risk are not enough; one needs to understand and apply the data in the context of disease pathophysiology and mechanismsⁱⁱ).

Since enormous amounts of data can be generated today for each individual, the challenge of personalized medicine is how to select/utilize these data in the most informative and cost-efficient manner. Data may also need to be gathered from each individual over time, so the active participation of both patients and healthy individuals, including their families and communities, is crucial for efficient data collection and monitoring. This also opens other

challenges such as the ethical use of samples or data, data security, confidentiality and ownership.

Action/research needed

Personalized medicine should be demonstrated by applications in promotion of well-being, disease detection, prevention and treatment. It should aim to demonstrate cost-effectiveness as well as health benefit, and it should be accessible to diverse populations. Instead of focusing on each disease individually, a systems medicine approach aims to account for the complex gene–environment, socio-economic interactions and co-morbidities that lead to individual-specific complex phenotypes.^{iii,iv}

A more unified and systematic approach to the research and applications of personalized medicine is needed, for:

- Chronic multifactorial diseases affecting large sections of the population.^{v,vi,vii}
- Rare diseases, which affect very few persons individually but represent a significant societal challenge collectively.^{viii,ix,x,xi}

The research should aim to establish or support a ‘pipeline’ needed to implement personalized medicine:

- A better understanding of diseases and their co-morbidities as well as resilience to disease^{xii} at the systems and mechanistic levels. Formulating hypotheses for biomarkers or targeted interventions aimed at disease prevention or therapy.
- Development of tools for utilizing/extracting/sharing new knowledge in the most informative and efficient manner (e.g. molecular profiling, biotechnology, diagnostics, ICT tools) in the most appropriate personalized setting (e.g. health care system, at home). Accelerating and facilitating regulatory approval paths for new medical products for personalized medicine (e.g. diagnostics, biotechnology, therapeutic or ICT solutions).
- Piloting the personalized medicine concept in real life settings (e.g. genetic/phenotypic screening programmes, responding to the paradigm shift in clinical trials which move away from unselected patient populations towards more individualized approaches in molecularly defined subgroups), demonstrating the health benefit and cost-effectiveness.^{xiii,xiv,xv}
- Sharing the huge amounts of data generated in the new and existing studies, while ensuring confidentiality and data security, and feeding this information towards the new discoveries (see above). Empowerment of individuals to manage their data.

An EU-wide approach to the utilization, maintenance and joining up of existing and future bio- and databanks should be supported:

- There are many cohorts in Europe where individuals have been monitored and sampled over long periods of time, with a wealth of health-related information. Some of these cohorts have been made possible through previous EU grants and have generated precious biobanked specimens which could now be comprehensively

characterized with ‘omics’ technologies. By linking these studies with long-term outcome data, they could become a “gold mine” for discoveries and innovation as well as for the validation of novel tools and solutions for personalized medicine.^{xvi}

- New studies should also be encouraged which collect/sample the relevant medical information in a longitudinal setting (health care system, workplace; also birth cohorts, natural history and epidemiological studies).^{xvii} Such studies will in time gather crucial information for implementing and demonstrating the power of personalized medicine.

Convergence of integrated monitoring/care and predictive medicine through deployment of ICT-supported integrated care services is also needed. This may include the development of refined and novel strategies to bridge the gap between (a) predictive disease modelling at the systems level and (b) the generation of simple rules to feed clinical or patient decision support systems.

Innovation needed in relation to the challenge

Action

Personalized medicine will not succeed without empowerment of patients together with the active engagements of the public (for example through patient groups) and of health care professionals. Both education and public awareness are thus important. Pilot studies that demonstrate the added value of the personalized medicine concept are also crucial, because success stories can influence decision makers (both EU and national) by, for example, shifting public opinion. The big data generated for personalized medicine will have to address the issues of privacy and ethics (such as how the data are used by insurance companies and other commercial or non-commercial agencies), as well as ownership. This should be addressed early and in each pilot study: as bad examples and any ensuing poor publicity could have a lasting negative impact on the implementation of personalized medicine, even if the study demonstrated benefit for health and cost-effectiveness.

Products

While this challenge will support innovative developments of ‘traditional’ products for early disease detection, prevention and treatment (e.g. diagnostic kits, ICT tools, new therapies), one can foresee that the shift to more participatory medicine will also open new business models and new products beyond the ‘traditional’ medical products.

Success criteria

- Research – new knowledge and understanding of diseases (e.g. early development of disease) at both the mechanistic and systems levels, i.e. with models integrating genetic, phenotypic (metabolome, metagenome, other relevant ‘omes’) and environmental factors with discoveries of relevance to personalized medicine (new biomarkers or disease pathways to target).
- Innovation – discovery and development of new solutions for personalized medicine (biomarkers/diagnostics), new products or business concepts.
- Economy – demonstration of cost-effectiveness of personalized medicine in national health care systems, with reliable estimates of how its implementation

would impact national economies. New business models and potential for generating new jobs.

- Health care – active engagement of health care and public health professionals as well as patients and their families in support of implementing personalized medicine.
- Public health – demonstration that the implementation of personalized medicine (e.g. in pilot studies) may decrease the incidence of specific non-communicable diseases and improve public health and wellbeing.

Internationalization and collaboration

In addition to existing international initiatives in research (e.g. biobanks, exposome research, clinical trial networks), this Societal Challenge should support international activities towards the piloting and implementation of personalized medicine. For example, in addition to developed countries, many developing countries face a rapid increase in the incidence of diabetes and other chronic diseases (China, India, Mexico, for example). The EU could play a role in supporting collaborations in the context of personalized medicine with these or other countries in specific disease areas of common interest. In addition to spreading the concept of personalized medicine to other health care systems, this could also open new business opportunities for EU companies.

Bottlenecks

Where are the bottlenecks and how can they be alleviated?

There are many ‘silos’ in the health care, public health and social service systems; personalized medicine needs joint engagement of researchers and health care professionals as well as the public. This Challenge thus needs to support active engagement of all the key stakeholders towards the implementation of personalized medicine. One of these key stakeholders is EMA, whose active involvement in the promotion of personalized medicine approaches is needed.

Even in research itself, scientists engaged in systems medicine speak many ‘languages’ and use different tools. Support and training for interdisciplinary teams and for active participatory communication are thus important.

Risks

What are the risks and how can they be minimized or avoided?

Research may focus on developing exclusive medicines that generate marginal improvements in treatment at great expense, and may only be accessible to a small, wealthy population. There are economic and access gaps where only the rich may benefit – both in terms of rich patients, but also access to the data and to the necessary subsequent interventions may only be available to the wealthy or privileged researchers or institutions. This would be the exact opposite of what this Challenge is about. This risk should thus be easily recognizable and therefore avoidable. At the opposite extreme, this research could develop therapies for rare diseases that would significantly benefit a very limited number of patients at quite high costs, posing the issue of sustainability for health care systems.

Ethics/confidentiality/privacy and data ownership have currently not been adequately addressed, and this may shift public perception against the concept personalized medicine. This Challenge should thus require that these important aspects are adequately addressed in every project.

Gaps

Where are the gaps and how can they be closed?

EU countries have different health care systems and regulations, so that piloting and implementing personalized medicine across different Member States may prove challenging. This is a political problem which will be difficult to solve in near term. One solution to alleviate this is to pilot personalized medicine separately in different countries if necessary. Then, based on the lessons learned, any necessary changes in national health care systems can be supported.

While the concept of personalized medicine is very attractive ‘on paper’, many doubts exist about its added value for public health and national economies. Success stories are needed (e.g. the successful development of targeted therapies for rare diseases).

‘Omics’ technologies are expensive, so there is a clear need for more affordable solutions if one is to use the information extracted from ‘omics’ data in personalized medicine setting.

Most health care professionals, as well as the general public, do not really know what the implementation of personalized medicine would mean in practice, and why one should change from ‘business as usual’. Again, the demonstration and communication of success stories, through pilot studies, are needed.

Game changers

What are the game changers that would significantly help to meet this challenge and how can they be developed and implemented?

If it fulfils its promise and avoids the risks, personalized medicine has the potential to bring enormous benefits in diverse medical fields and to public health. The game changer will be when the public supports the changes in health care systems that will be needed to implement personalized medicine. This can be achieved by success stories as well as by the generation of new business models.

Role of the public sector

What is the public sector’s role and how can it best be implemented?

The role of the public sector (universities, university hospitals, research institutes) is to promote extensive deployment of integrated care services. This will open multiple areas of innovation covering a wide spectrum from services, applications and novel ICT approaches to innovative biomedical equipment, which in turn will enable functional networks of SMEs to grow.

The public sector may also have a key role in early piloting of new concepts for personalized medicine, and may also act as an ‘honest broker’ for issues such as validation (e.g. data, biomarkers), data security, ethics, and so forth. Publicly funded hospitals and other publicly

funded services can take the lead in piloting and disseminating the implementation of personalized medicine in collaboration with businesses and academia.

Another important role of the public sector is to contribute to the design of pivotal clinical trials of “targeted therapies” so that considerations other than “return on investment” are taken into account. This would help address issues such as duration of therapy, preventing overtreatment and the unnecessary long duration of use of expensive targeted drugs. For this to happen, there must be a share of financial risk between academia and industry.

Strong areas for industry and SMEs

Bottom-up activities

Personalized medicine offers great potential for the development of innovative products (e.g. ICT, diagnostics, advanced gene- and cell-based therapies) and the generation of new business models. Furthermore, it potentially engages multiple industry sectors, including among others diagnostics/analytics, pharmaceuticals, food and nutrition, health insurance and ICT.

Industrial roadmap

As the era of blockbuster drugs has come to an end, personalized medicine represents a new frontier for pharmaceutical companies, whose efforts are increasingly focused on “patient-tailored” approaches. Recent increased investment in the area of rare diseases by major pharmaceutical companies clearly indicates that this direction is being followed.

Large corporate medical entities such as insurance companies and pension funds, as well as hospitals, clinics and other health care and social service organizations, have important large databases which if linked with administrative and environmental data can provide the data for innovative applications of personalized medicine. An example of this can be seen in the joined up health and wellbeing databases of Wales and Scotland.

Strong areas to support integrated activities for each of the big challenges

Social science and humanities

Implementation of personalized medicine will require the active participation of the public: each individual will need to take more responsibility for his or her own health (for example monitoring). Although we still do not know how this will work in practice, it is a potentially big shift in public health. It would thus be relevant to better understand how personalized medicine may affect, for example, social interactions and networking, or sharing of personal data.

Responsible research and innovation, including gender aspects

Personalized medicine carries several risks related to data ownership/privacy and ethics, and these should be adequately addressed.

Climate and sustainable development

(1) Understanding the role of the changing environment on individuals' health is essential if one is to implement personalized medicine. (2) When it comes to healthy life and disease prevention, food and nutrition are important factors to consider. More targeted interventions (therapies and prevention) may have decreased environmental impact (for example through the decreased use of pharmaceuticals such as broad spectrum antibiotics).

Interdisciplinary activities

Personalized medicine requires interdisciplinary activities at the levels of both research and implementation.

SWOT analysis

<p>Strengths</p> <p>Comparatively strong health care system infrastructures to conduct clinical studies. Longitudinal/prospective cohort studies. Strong basic research. Rapid advances in 'omics' including decreasing costs.</p>	<p>Weaknesses</p> <p>Insufficient interdisciplinary, existence of 'silos'. Different health care systems and regulations across EU. Insufficient entrepreneurship, making implementation of personalized medicine in real life challenging. Lack of joined up databases. Lack of training of health care and other providers.</p>
<p>Opportunities</p> <p>Need for new business models. Need for improved public health. Need for change to health care systems to reduce the costs.</p>	<p>Threats</p> <p>Inadequately addressing the risks associated with personalized medicine, such as issues of data privacy/ownership and security. Resistance to change. Despite demonstrated success, public and health care professionals do not support implementation of personalized medicine.</p>

Key References

- i. Mirnezami R, Nicholson J & Darzi A (2012). Preparing for precision medicine. *N Engl J Med.* **366**(6): 489–91.
- ii. Virtue S & Vidal-Puig A. (2008). It's not how fat you are, it's what you do with it that counts. *PLoS Biol.* **6**(9): e237.
- iii. Bousquet J. *et al.* (2011). Systems medicine and integrated care to combat chronic non-communicable diseases. *Genome Med.* **3**(7): 43.
- iv. Coordinating Action on Systems Medicine Across Europe (www.casym.eu/) [accessed 4 July 2014]: EU-CASyM Joint Workshop: European Systems Medicine roadmap discussions. Brussels, 29 November 2012.
- v. A Systems Biology Approach to Study Metabolic Syndrome. Editors: M. Orešič, & A. Vidal-Puig. Springer Verlag, NY; 2013. ISBN: 978-3-319-01007-6 (Print) 978-3-319-01008-3 (Online).

- vi. Lenfant C (2013). Prospects of personalized medicine in cardiovascular diseases. *Metabolism* **62** Suppl 1: S6–10.
- vii. Jia W (2013). Personalized medicine of type 2 diabetes. *Front Med.* **7**(1): 1–3.
- viii. Communication from the Commission on Rare Diseases: Europe’s Challenge: http://ec.europa.eu/health/ph_threats/non_com/docs/rare_com_en.pdf [accessed 26 June 2014].
- ix. Hamburg MA & Collins FS (2010). The path to personalized medicine. *N Engl J Med.* **363**(4): 301–4.
- x. Garber AM & Tunis SR (2009). Does comparative-effectiveness research threaten personalized medicine? *N Engl J Med.* **360**(19): 192–7.
- xi. Ng PC, Murray SS, Levy S & Venter JC (2009). An agenda for personalized medicine. *Nature* **461**(7265): 724–6.
- xii. Friend SH & Schadt EE (2014). Translational genomics. Clues from the resilient. *Science* **344**(6187): 970–2.
- xiii. Auffray C, Charron D & Hood L (2010). Predictive, preventive, personalized and participatory medicine: back to the future. *Genome Med.* **2**(8): 57.
- xiv. Hood L & Friend SH (2011). Predictive, personalized, preventive, participatory (P4) cancer medicine. *Nat Rev Clin Oncol* **8**(3): 184–7.
- xv. Trusheim MR, Berndt ER & Douglas FL (2007). Stratified medicine: strategic and economic implications of combining drugs and clinical biomarkers. *Nature Reviews Drug Discovery* **6**(4): 287–93.
- xvi. Bougneres P & Valleron A-J (2008). Causes of early-onset type 1 diabetes: toward data-driven environmental approaches. *J Exp Med.* **205**: 2953–57.
- xvii. Editorial (2013). Longitudinal thinking. *Nat Biotechnol.* **31**: 177.

7.3 Working group report: ICT for health

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What is the challenge?

The application of ICT has become routine in medical care, with widespread reliance on medical imaging, surgical instrumentation and physiological measurement. Continual advances in biomedical physics and signal processing, mathematical and statistical analysis, together with affordable access to high performance computing, have also started to demonstrate potential for *in silico* modelling of patient-specific physiology from sub-tissue to organ levels, supported by platforms enabling non-technical users to build person-centred workflows [1]. This is paralleled by radically different approaches emerging from developments in sensor networks, behavioural modelling and peer-to-peer support. For example, mobile health alone represents an expanding market already worth billions of euros from around 100,000 applications expected to be published by Q1 in 2014, currently targeting chronically ill patients and health- and fitness-interested people [2]. The impact of these technologies will be increased with a more strategic approach to their development and evaluation [3]. Taken in combination, ICT offers the potential to bring health care from clinical centres into the everyday life of the citizen, in health promotion as much as for health care and disease prevention. This involves significant investment across the research and innovation pipeline from smart sensing, the internet of things and multi-scale modelling, through big data and artificial intelligence for deep modelling of person-centred data with contextual and specialist information, to translation into new models of care [4–6].

Research is needed to establish the evidence for integration of ICT for health solutions in national health systems, building on current technological infrastructure through targeted applications and focused evaluation of these applications with long-term follow-up. It will also involve technological development and innovation to bridge the gap between raw technologies and business intelligence, amounting to a technologically enabled culture shift in health care but also in lifestyle promotion and wellbeing.

A **dual focus** is therefore needed: 1) focus on **person-centred health care delivery**, also integrating health and social care and considering the environment and community setting of the individual; and 2) a separate focus on **wellbeing and prevention** to identify trends towards ill health and so strive to keep people away from unnecessary care and be proactive.

Why is this a challenge?

The first challenge is to strengthen the growing body of evidence about the contribution of ICT for health to cost reduction, care efficiency, quality of life and equity of access to health and care services. Likewise there is still a lack of integration of ICT for health and prevention solutions in national health systems. Moreover, the use of ICT with deprived, hard-to-reach, and vulnerable users and communities is yet to be fully explored. Furthermore, health care needs to become firmly person-centred with a culture shift where the individual will take greater ownership of his or her state of health aided by ICT. Finally, few advanced integrated ICT solutions are available which assist patients with chronic conditions to really compensate for their illness and disabilities.

Action/research needed

- Extensive quantitative and qualitative research is urgently required to create a body of knowledge and evidence that ICT for health and prevention contributes to cost reduction, efficiency, reduction of invasiveness, safety, improvement of patients' quality of life and equity of access to health services.
- This requires close collaboration between research and academic institutions, the public health sector and the private sector to register and conduct research and more important make the results available and accessible to policy makers.
- Integration of ICT for health and prevention in health and public health systems requires development of national eHealth policies and revision of legal frameworks that will ensure proper penetration, use and accountability at both local and national levels. Investments should be prioritized into research to determine how eHealth policies most efficiently lead to integration of ICT for health within health systems, in various economic settings.
- The joining-up of the big data of health, public health and social care such that ICT can really happen (e.g. integration of results of various screening programmes throughout EU Horizon 2020) should sponsor research to identify best practices in this area, in order to ensure integration of EU countries' results.
- Research is needed on the application of big data to health care analytics, combining modelling, optimization, predictive analytics and business intelligence of genomic data, clinical trial data, electronic health records, personal health records, behavioural markers, claims data, and research study data (health, administrative and environmental data).
- Demonstration projects using the results of this research would allow payers to be able, among others, to monitor efficacy and adherence to drug and treatment regimens and to detect trends that lead to individual and population wellness benefits. Organizations could gain insights to strengthen financial and budgetary performance, deepen consumer-centric relationships, and improve the way health care is conceived and delivered for better outcomes across the entire spectrum of health industries.

Innovation needed in relation to the challenge

Action

- Health care needs to embrace ICT for health as integral part of its business model. This would require changing/reengineering some of the workflow, the procedures, training of personnel and the whole issue of health data management.
- Public health officials should focus on the benefits and provide guidance on how best to use ICT for health promotion and disease prevention. Surveillance, disease, and other health data can be collected, linked, analysed and interpreted online. This can give public health policy- and decision-makers an opportunity to act on data in real time rather than only historical data as well as identify vulnerable populations at risk and model and evaluate interventions.
- The EU can lead by providing the necessary frameworks and funding for such innovative efforts (e.g. FP7 funded exposome projects).
- The private sector (health and ICT sectors) should invest in initiating and scaling up ICT for health projects which can be used as models for partnerships and innovation collaborations.
- Deprived, hard-to-reach, and vulnerable communities (e.g. elderly, deprived) need particular attention since they often require the most health care and social services but have the least access and most potential barriers to ICT. Significant innovation in this field might be needed to fill the gap towards other ICT global players (USA, Japan), for example in the field of handheld devices and mHealth, aging population services, and so on. It will also be important to try ICT applications in different geographic locations and to learn from the extensive use of some forms of ICT in the developing world.
- The focus should be on prevention and wellbeing, not just on health care delivery.
- There is an opportunity for the entire health sector (including social care and public health) to serve as a model of best practice in sustainable development using ICT as one of the building blocks.

Products

- Pharmaceutical drugs, medical devices, tele-health and tele-care systems and user-interfaces, computer-integrated technologies, decision aids including handheld devices and mHealth, artificial organs, others.
- ICT for health in drug management can be used in inventory and stock management so that no expired drug will remain on the shelves and no shortage of drugs will be faced.
- ICT for health can be used as part of computer-assisted and artificial intelligence services to show drug integration, alerts, and decision support for diagnosis and therapy. ICT for health can be best connected to medical devices, computer-integrated technologies, and artificial organs to capture vital signs and record them in electronic medical records, alert systems, drug/therapy delivery systems, and so forth, also in a closed-loop fashion. ICT for health can provide an integration platform for diverse medical devices by multi-modal sensor fusion, data aggregation, analysis, reporting and predictive inference.

- ICT for health can improve care delivery in poorly accessible geographical areas by means of tele-health and tele-care systems provided by bidirectional user-interfaces (with the main health care facilities), biomedical/biorobotic drug delivery systems, care delivery devices or robots, or other automatic or semi-automatic diagnostic devices.
- A lot of the technology exists already; rather it is the access, application, integration into workflows, training, and evaluation that are the issues.
- There will be new ICT processes and applications developed for other sectors than health, so there is a real opportunity to learn from these sectors in their uses and applications of ICT – for example, agricultural extension services have attached weather reports to pay-as-you-go cellular phone cards so that farmers in the developing world will always get these reports.

Success criteria

Research

Building a body of knowledge that can inform policy and decision making. There need to be inexpensive and rapid standardized approaches for evaluation of ICT, and different users to speed up this process. One of the key success criteria in research might be the use of e-learning, disseminated at the level of the EU.

Innovation

New ways of using ICT for health can create value from data collected and stored in ICT systems. Data collected for other purposes can help better understand human and environmental health through data mining, linking and trend analysis. Use of data from social media sources can enrich the understanding of social behaviour and its impact on health. Learning from the developing world might be a plus, as well as new uses of existing technology or processes.

Economy

ICT in general can save costs by adding value to data, reducing routine tasks, and allowing faster processing of transactions. This can be applied in the health sector. Cost needs to be part of the evaluation. Automatic assumptions about sustainability should be explored, questioned and monetized e.g. in preventive care and public health as well as sustainability of the entire health sector.

Health care

ICT should be used towards improving quality of health care, reaching remote areas, and vulnerable populations. Social services and public health need to be integrated with health care.

Public health

Aggregating data from multiple sources and formats can provide a more comprehensive view of the world. The focus needs to be on health promotion, disease prevention and wellbeing (e.g. lifestyle improvements) rather than just disease treatment.

Internationalization and collaboration

ICT for health is a global issue. Health does not recognize national boundaries. Health data travel across the boundaries and trans-border data flow is a reality. ICT for health solutions is developed in one country and deployed in many others. The internet is a global resource that goes beyond one country or region. Multilingualism, multicultural challenges, international laws, and partnerships need to be considered. Ethical issues around data confidentiality, IP, costs, and data ownership need to be explored and communicated. A lot can be learned from developing nations where ICT has been innovatively developed and applied to deal with existing constraints.

Bottlenecks

Where are the bottlenecks and how can they be alleviated?

- Not enough is done to create the evidence. There is a huge gap between money spent on pilot projects and money spent on their evaluation. The culture of evaluation (including cost benefit) has not been well rooted in ICT for health and prevention yet. This can be alleviated by enforcing policies that all projects should be formally evaluated. Academic and research programmes should allocate funds and human resources for training, research and evaluation. ICT for health projects and research initiatives should be internationally registered and transparent.
- Consider establishing standardized rapid and inexpensive evaluation protocols otherwise the issue of proven efficacy (as well as acceptability, cost, and sustainability) may stop progression.
- Training and access to technology are major issues for all users.

Risks

What are the risks and how can these be minimized or avoided?

- Research from and for the more developed countries might not reflect the situation and challenges in all countries, creating biases. Research, training and evaluation might be implemented by those who can afford it, while solutions might be given to all regardless of local situations. This can be alleviated by ensuring equity in distribution of funds and research grants among partners.
- Issues around ethics/confidentiality, also IP and data ownership, need to be urgently considered.

Gaps

Where are the gaps and how can they be closed?

There is a knowledge gap on the value of ICT for health and prevention especially among practitioners. This can be bridged by better formal education and training as well as in-service training. This will encourage better research, implementation, monitoring and evaluation. This gap is even bigger for the potential applications of ICT in the areas of wellbeing and prevention – as well as applications in deprived, vulnerable and isolated communities.

Game changers

What are the game changes that would significantly help to meet this challenge and how can these be developed and implemented?

The collaboration and partnership between the public and private sectors based on common understanding (and not only on profit for the commercial sector) would be a game changer. This can be made a reality through public and open fora, competition, and clear definition of needs and policies. Case studies are needed of applications that work, have been evaluated, and which are tried in different communities in time and space.

Role of public sector

What is the public sector's role and how can this best be implemented?

The public sector should develop public policies and legal frameworks, ensure sustainable funding, transparency, a better understanding of needs, and openness for change. Resistance to change is a social challenge, and not technological in nature. As the public sector is usually cautious, it needs to be educated and well informed. Joining up of public databases while protecting confidentiality etc. will be essential.

Strong areas for industry and SMEs

- Industry and SMEs develop products based on market research and needs assessment. The big challenge in ICT for health is the availability of solutions looking for problems. SMEs should try to understand what the challenges are and come up with cost-effective, user-friendly and easy-to-use solutions, especially for ageing populations, young people, busy managers and digitally-illiterate populations.
- Industrial roadmaps should be developed towards integrated and interoperable solutions, again learning from developing nations when appropriate.
- Industry and SMEs could help integrate into small communities' ICT to support health, wellbeing and prevention in housing, transportation, schools, and not just traditional health and social care delivery.

Strong areas to support integrated activities for each of the big challenges

The overarching theme will be public health and health care changes, important aspects for rising costs and declining economy, and urbanization and changes in demography.

For each challenge the following overarching areas and cross-cutting activities should also be addressed:

- Social science and humanities
- Responsible research and innovation, including gender aspects
- Climate and sustainable development
- Interdisciplinary activities

SWOT analysis

<p>Strengths</p> <p>New technologies and increased access to broadband even in low-income settings.</p> <p>Health care expectations from ICT are high, so new products and applications are often sought and welcomed.</p> <p>Large knowledge base exists.</p>	<p>Weaknesses</p> <p>Not enough evidence on benefits and not enough investment in evaluation and training.</p> <p>Absence of coordinated and coherent application of research outcomes.</p> <p>Cross-sectoral collaboration as a routine still not the norm.</p> <p>User-centred design also still not the norm. Older frailer cohorts often left out of consultation.</p>
<p>Opportunities</p> <p>Industry/SMEs/academia collaboration, in and beyond the health sector.</p> <p>New appreciation of the importance of ICT in health and development.</p>	<p>Threats</p> <p>IP issues and commercial drive of vendors.</p> <p>Competitive rather than collaborative research.</p> <p>Older people seen as not able or afraid to take -up technology.</p>

Key references

- VPH-FET. VPH-FET Research Roadmap Advanced Technologies for the Future of the Virtual Physiological Human, 2011, *accessed on 23/06/2014 at* www.vph-institute.org/upload/vph-fet-final-roadmap-1_519244713c477.pdf
- research2guidance, mHealth App Developer Economics 2014. The State of the Art of mHealth App Publishing, *accessed on 30/6/2014 at* research2guidance.com/pharma-companies-far-from-realizing-their-app-market-potential
- WHO, Global Observatory for eHealth series Vol 3, mHealth - New horizons for health through mobile technologies, *accessed on 30/6/2014 at* www.who.int/goe/publications/goe_mhealth_web.pdf
- Department of Health, UK (2011). Whole System Demonstrator Programme - Headline Findings.
- W. Raghupathi & V. Raghupathi (2014). Big data analytics in healthcare: promise and potential. *Health and Information Science and Systems*. 2: 3.
- McKinsey Global Institute, (2011). Big data: The next frontier for innovation, competition, and productivity. *Accessed on 30/6/2014 at* www.mckinsey.com/insights/business_technology/big_data_the_next_frontier_for_innovation

7.4 Working group report: Population health and health promotion

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What is the challenge?

Population health and health promotion refers to the process of enabling people to increase control over their health and its determinants, and thereby improve their health.

Health promotion can be classified at two levels. The first level is universal preventive interventions. These offer all members of a social or geographical unit new activities or new services helping them overcome current or future challenges. The second level is targeted preventive interventions. These include individuals that are at risk for a problem.

The challenge of "population health and health promotion" is to generate new knowledge about how to promote the mental and physical health of the countries' populations.

The challenge addresses four levels: who should be targeted; what should be targeted; and when and how the interventions should take place.

Health promotion is a big topic. Individuals with mental disorders, depression, anxiety and antisocial behaviour, should be targeted and prioritized because mental illnesses contribute more to the global burden of disease in Europe than any other illnesses. Obesity is clearly another target. It carries with it all sorts of consequences and there is a lot of interest in whether these consequences are differentially related to obesity in childhood and middle adult age. Smoking among girls remains an issue and is hazardous for development and offspring. Illicit drug use and alcohol binge drinking cause concern. Social isolation among the elderly is common. We need to know more about the individual, social and political determinants for health. Knowledge about determinants and causal mechanisms are crucial for creating effective population-based and targeted interventions.

Why is this a challenge?

Because very many individuals suffer from mental illness, for example depression, anxiety, psychosocial and behavioral disorders, starting early in life and often lasting for a long time, the cost for society becomes very high. In fact, brain diseases and mental disorders in particular constitute the most enormous financial and societal pressure on health care and welfare systems with estimated yearly costs in the European Union of approximately 800 billion euros – more than cancer, cardiovascular disease and diabetes combined. Between 1990 and 2010 the global burden of depressive disorders alone increased by 37.5%. By 2030 unipolar depression is predicted to be the number one contributor to the global burden of disease. For children at risk for developing symptoms of mental illness, such as emotional disorders due to abuse and neglect and poor parenting, depression, antisocial behaviour and delinquency, efforts are needed to break the developmental pathways linking early risk factors to later problems. Therefore, early intervention is generally emphasized. Eliminating the

initial risk factors in the developing chain is essential. Causal and evaluation research can take advantage of existing programmes and population-based data bases.

Action/research needed

A more holistic knowledge base to strengthen the overall public health situation in Europe is needed for:

- Mental illness and to explore the relationship between mental health, wellbeing and resilience to disease processes.
- Translating the solid knowledge about risk factors for mental health problems into concrete procedures for prevention and treatment.
- More effectively disseminating the results from research to relevant agencies (health care, education), as well as to individuals.

Focus of applications can be on different outcomes and comorbidity. Mental disorder is a significant risk factor for non-communicable diseases (NCD). Depression is a substantial contributor to burden of ischemic heart disease, and likewise somatic disease can lead to mental problems. The aims are to obtain new knowledge about the big population-based health problems, and to demonstrate programmes for health benefit, cost-effectiveness and generalizability to diverse populations. Understanding which types of prevention programmes can become building blocks for improved population health across cultures is needed.

Concrete recommendations for a research programme

- *Mental illness*: identify causal mechanisms underlying the development of mental disorders that could serve as targets for effective interventions.
- *Lifestyle contributors to chronic disease development*: Obesity, smoking specifically among young girls, binge alcohol drinking, illicit drug use.
- *Pan European health promotion*: how can interventions which have proved successful for combating mental disorders in some countries be adapted so as to be effective in other countries where economic, social and cultural factors differ?
- *Turning points in adult age*: explore how experiences in adult life may make a decisive difference to people who have been placed at risk as a result of adverse experiences in childhood.

Understanding the huge individual differences in developing mental illness and NCD is essential for knowing what to do for prevention and repair. Early intervention is important because it can modify disease-promoting behaviour while it is still malleable, and because disease prevention is considerably less costly than repair. Turning points in adult age refer to the phenomenon of a change from a maladaptive to an adaptive life trajectory as a result of some life experiences or intervention programmes. One type of implementation is to reduce risk factors for disorders, but risk factors for mental and physical disorders are multifactorial. Risk factors include genetic liability, experiences of parental inadequacy, social and environmental circumstances such as minimum age for access to alcohol, availability of drugs and communities' tolerance of their use. It remains to be seen how much these factors vary in prevalence over time and place and whether environmental modulation is possible.

Innovation needed in relation to the challenge

Action

The most successful innovation will be concrete procedures either to prevent or treat mental disorders and NCD.

Products

Online and mobile technologies, ICT, medical devices, drugs and social media can improve methods of screening and collection of data in population-based studies. Traditional methods like questionnaires, interviews, tests and experiments, can be supplemented with measurements utilizing technological devices. Age-appropriate adaptation of ICT tools from infancy to old age can open the way to new products. While there are many initiatives for exploring how technology can assist diagnostics and treatment in somatic medicine, mental health has lagged behind.

Success criteria

- Research – discovery of causal mechanisms in the association between risk factors and mental illness. New understanding of how to prevent and combat mental and physical ill-health in an efficient way. Replicate original programmes in different socio-economic contexts and cultures to identify their limits.
- Innovation – discovery and development of new technology, ICT, new products or business concepts for use in health research.
- Economy – economic science extending its ability to understand the true costs of programme interventions to help decide between alternatives and guide thought.
- Health care – programmes should rest on a well-coordinated and integrated health promotion and prevention service. Properly implemented programmes reduce the need for health services.
- Public health – decrease the burden of mental problems in society.

Internationalization and collaboration

European databases of biobanks and population-based longitudinal cohort studies are available for research across countries. Overview of preventive interventions targeting different areas is helpful.

Bottlenecks

Where are the bottlenecks and how can they be alleviated?

Most of the money spent on health research in Europe is spent on developing cures for those who have become ill, while only a small part is spent on promoting health and preventing people from becoming ill. We need a balance on money spent on cure and money spent on prevention.

Risks

What are the risks and how can they be minimized or avoided?

Most of the money spent on health research in Europe is spent on physical disease, while only a fraction is spent on mental illness. We need a balance on money spent on physical illness and money spent on mental disorders.

Gaps

Where are the gaps and how can they be closed?

The goal must be a substantial reduction of NCDs and mental disorders in Europe. We must identify the causes and develop effective interventions. More effort should be invested into understanding disease mechanisms and their environmental modulation.

Changes to the environment may not benefit all. Genetically informed studies of resilience and adaptation can uncover how environmental stressors causally affect mental health and why population-based interventions do not benefit all.

Game changers

What are the game changers that would significantly help to meet this challenge and how can they be developed and implemented?

Mental disorders and NCD constitute a major burden on society and any substantial progress in understanding the underlying causal mechanism or identifying effective interventions will be a game changer for society.

Role of the public sector

What is the public sector's role and how can it best be implemented?

Progress will only be possible if we have high quality data. The role of the public sector, universities, hospital, schools, institutes, prisons, and so forth, is to contribute with precise and up-to-date data.

Strong areas for industry and SMEs

Bottom-up activities

Population health and health promotion, for example telemedicine, can benefit from innovative products such as online and mobile technologies, ICT and diagnostics.

Industrial roadmap

Mental health is one of the main causes of sick leave and contributes significantly to the work environment and productivity.

Strong areas to support integrated activities for each of the big challenges

Social science and the humanities

It is relevant to understand the role of mental features such as self-control, planning, self-reflection, and active personal agency in interventions.

Responsible research and innovation, including gender aspects

High regard of research ethical approval is a prerequisite when conducting research in health issues. Gender is important because females and males have different patterns of mental and physical disorders across different age groups. The underlying causal mechanisms may differ across gender, necessitating different strategies for interventions.

Climate and sustainable development

Food and nutrition are important factors for population health. A global perspective on population health and health promotion, especially for the children and their mothers, should be supported.

Interdisciplinary activities

Interventions requires interdisciplinary activities both in research and implementation.

SWOT analysis

<p>Strengths</p> <p>Longitudinal population-based cohort studies with research biobanks.</p> <p>Strong tradition with many intervention programmes for different conditions.</p>	<p>Weaknesses</p> <p>Insufficient insight in causal mechanisms of different conditions to be targeted.</p> <p>Demanding and time consuming clinical work offer less time to do interventions.</p>
<p>Opportunities</p> <p>Need to start early in kindergarten and schools to prevent mental illnesses.</p> <p>Need for improved mental health and lost years of work in all countries.</p> <p>Need for using new technology when conducting research and implementing programmes.</p> <p>Need for change from costly treatment to cost-effective prevention.</p>	<p>Threats</p> <p>Resistance to change behaviour.</p>

Key references

- Barry MM, Clarke AM, Jenkins R & Patel V (2013). A systematic review of the effectiveness of mental health promotion interventions for young people in low and middle income countries. *BMC public health* **13**(1): 835.
- Campbell F, Conti G, Heckman JJ, Moon SH, Pinto R, Pungello E & Pan Y (2014). Early Childhood Investments substantially Boost Adult Health. *Science* **343**(6178): 1478–1485.
- Charlson F, Moran A, Freedman G, Norman R, Stapelberg N, Baxter A, Vos T & Whiteford H (2013). The contribution of major depression to the global burden of ischemic heart disease: a comparative risk assessment. *BMC Medicine* **11**(1): 250.
- Cuijpers P, Beekman AT & Reynolds CF, 3rd (2012). Preventing depression: a global priority. *Journal of the American Medical Association* **307**(10): 1033–1034.
- Ezzati M & Riboli E (2012). Can noncommunicable diseases be prevented? Lessons from studies of populations and individuals. *Science* **337**(6101): 1482–1487.
- Gore FM, Bloem PJ, Patton GC, Ferguson J, Joseph V, Coffey C, Sawyer SM & Mathers CD (2011). Global burden of disease in young people aged 10–24 years: a systematic analysis. *Lancet* **377**(9783): 2093–2102.
- Heckman JJ (2006). Skill Formation and the Economics of Investing in Disadvantaged Children. *Science* **312**(5782): 1900–1902.
- Jacka F, Mykletun A & Berk M (2012). Moving towards a population health approach to the primary prevention of common mental disorders. *BMC Medicine* **10**(1): 149.
- Melhuish EC (2011). Preschool Matters. *Science* **333**(6040): 299–300.
- Munoz RF, Beardslee WR & Leykin Y (2012). Major depression can be prevented. *The American Psychologist* **67**(4): 285–295.
- World Health Organization (2013).: The European Mental Health Action Plan.
- World Health Organization: Global action plan for the prevention and control of non-communicable diseases 2013–2020.

7.5 Working group report: Infectious diseases at large

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What is the challenge?

There are two main elements to this challenge:

- Specific disease or infectious pathogen-generated threats.
- Inefficient or maladapted research and development processes.

While the last two centuries have seen a tremendous reduction in the mortality and morbidity resulting from infectious diseases, there remain important well-characterized infections against which we still have no effective preventive or therapeutic interventions. Disturbingly, there is the rapidly growing emergence of new pathogens which demand the development of new anti-infectives or vaccines, as well as of familiar pathogens which have acquired resistance to available interventions (and in particular antimicrobial resistance – AMR), or are evading conventional control strategies. Climate change and emerging or re-emerging zoonosis are compounding these challenges.

Addressing these threats presents a number of challenges:

- The current R&D pipeline for anti-infectives and vaccines has a high attrition rate due to the need for elaborate pre-clinical development, costly clinical trials to demonstrate safety and efficacy, and the rapid development of resistance to new antimicrobials once they enter into use. To address this an improved and accelerated development pathway is needed, combining identification of critical genes both from the host and the pathogen side, for susceptibility and resistance, better identification of safety signals in animals and early-stage human trials, a better understanding of extrapolation of animal studies to human use, and more efficient approaches to the conduct and analysis of clinical trials.
- Unnecessary or prolonged use of anti-infective treatments adds to societal costs and resistance, which could be addressed by better diagnostics prior to treatment, as well as prevention rather than treatment. Alternative therapeutic approaches augmenting host defences, e.g. immunomodulators, or exploiting other metabolic or physiological pathways and mechanisms, must also be examined as alternatives to interventions relying solely on direct interference with microbial replication. Diagnostics currently detect a pathogen, rather than guide the selection of management strategies targeted to the stage of the evolution of the patient's illness, and when it guides treatment, it often entails a delay to a correctly targeted intervention.
- The emergence of new diseases, whether actually newly introduced or only newly characterized, demands a capacity for research readiness and the ability rapidly to integrate findings from multiple disciplines. The conventional investigator/interest-driven research model is slow, capricious, and leaves gaps, along with unproductive (and sometimes unethical) duplication.

Why is this a challenge?

The public and individual health gains made over the last two centuries, and in particular the last 50 years, are being eroded by the emergence of resistance to existing anti-infectives, and the emergence of new infective disease threats as a consequence of increasing population, population mobility, changing practices, and changing climate. The pace of discovery and innovation is outrunning our ability to integrate and apply, thus to obtain the maximum utility along the value chain from discovery to intervention or product. Societal expectations of access to the benefits from science, especially in health, have increased in countries at all levels of development. At the same time, economic constraints are demanding greater efficiency and selectivity even in technologically advanced countries; this is mirrored in declining investment in health research. However, the increasing explication of the connections between infections and other disease categories, such as cancer, NCDs, other chronic and immunological diseases, mental health, senescence and dementia, provides a profound justification and incentive to focus investment in research on understanding and controlling acute infections and preventing or curtailing chronic infections and their long-term impacts. Better understanding patient safety aspects, infection control, and development of best practices for diagnostic and rational use of antibiotics, will also be needed.

Action needed

These challenges cannot be efficiently addressed by individual teams but require:

- Commissioning and performing research which has a prospect of application in view, and which builds the necessary collaboration between disciplines from the outset. A new paradigm of application-driven research should be established which may comprise elements from fundamental biomedical science to clinical research, epidemiology, engineering, and so forth, and which attends to the societal acceptability of research outputs. This also entails a more flexible approach to clinical trial design to absorb accruing findings and adapt direction accordingly, while maintaining scientific standards and validity as well as the ethical integrity of the research.
- Concerted and focused R&D bringing together academia, public health institutions, SMEs and industry, and with input from regulators, policy makers and civil society. Involvement of all actors will be critical; SMEs in particular can play a key role and this should be explored. Creating and strengthening science parks or mixed campuses where academia, SMEs and industry share work space, engage in scientific exchange and joint projects, and augment the translational research capacity will be essential to increase European competitiveness in this area.
- Establishment of accessible, interlinked meta-databases comprising results from all attempts, irrespective of outcome (both positive and negative) to avoid duplication of fruitless paths, while providing improved understanding of these infectious agents.

Research needed

Vaccines

Research and development for vaccines against infections no longer controllable by antibiotics due to AMR, for example *Staph. aureus* and gonorrhoea, should be considered a top priority. Vaccines for malaria should remain a high priority to be included in the 2016–

2017 Horizon 2020 programme (as only HIV and TB were part of the 2014–2015 programme).

Parallel with vaccine development, it should be of high priority to invest in new vaccine platforms and/or improvement of existing ones: for multi-antigen delivery; for more comprehensive protection against strain variation; for more rapid manufacture and scaling-up to respond to events or increased demand; for improved immunogenicity and/or safety; for use in immunotherapeutic interventions; for greater public acceptability.

Research should also be considered into vaccines for severe emerging diseases where there is no specific therapeutic, or where the natural history of the disease or its context mean there would be no time or capacity to employ one quickly enough to avert mortality or morbidity.

Therapeutics including anti-infectives

Priority investments should be made into the discovery and development of novel antibacterial agents to treat diseases such as tuberculosis and gonorrhoea, and to control infections with *Staph. aureus* and multi-drug-resistant Enterobacteriaceae. Research should also as a priority target antivirals against influenza, respiratory syncytial virus and Herpesviruses (especially HSV and CMV).

Near- and medium-term priorities should consider exploitation of existing compound and product libraries to identify potential therapeutics for specific emerging infections, and further development of nucleic acid based therapeutics, e.g. siRNAs.

Diagnostics and host–microbial interactions

In this area, a top priority should be the exploration of modalities for controlling sepsis through more comprehensive understanding of signalling pathways, both for diagnosis and for interventions.

Horizon 2020 should also invest in the development of affordable point of care (POC) and near-patient diagnostic tests for multiple agents and capable of enabling differential diagnoses (e.g. disentangling fevers in different endemic settings), to identify and also to exclude, for more directed early therapy. This also includes polyvalent diagnostics systems covering large numbers of pathogens (bacteria, viruses, fungi) and possibly immune and other biomarkers for district hospital confirmation/public health reference use.

Research is also needed urgently to reassess the position of biomarkers for diagnostics – early detection of a specific disease (pathognomonic cluster of biomarkers), assessment of stage of evolution of illness, to monitor treatments, to capture interactions between communicable diseases and NCDs and/or comorbidities as well as to guide choice of therapeutic interventions.

In the medium term, studies should be supported which extend understanding of the aetiological connections between infection and inflammation, and cancer and other chronic disorders.

In the longer term, attention should be given to genome-wide association studies for specific infections to understand susceptibility to severe disease, poor outcomes and chronic complications – linking to interventions in both personalized medicine and population-based interventions.

Research should also be considered targeting the microbiome in health, disease, damage and recovery – interactions in immunological and chronic disease, manipulation of the microbiome for specific therapy, and for increased host fitness and disease resistance. Finally, analysing and describing intra-host pathogen population dynamics (beyond HIV) would prove extremely useful for improved understanding of disease evolution and for design of interventions, in acute and chronic infections.

Clinical management for diverse resource settings

Continued investment by the EC is needed on developing approaches to clinical trial design based on Bayesian statistics (adaptive clinical trials), on development of new regulatory pathways and on increasing the number of phase 1 exploratory clinical trials.

Improving standards to support innovation

Standards play an essential role in defining the critical path for efficient translation of new technologies and innovative products into clinical application for all stakeholders. However, until now there has been no strategic attempt to support cooperative standardization projects. A successful European initiative in this area would support public acceptance of medicines and the manufacture and sale of safe and effective medicines, vaccines and health technologies.

Innovation needed in relation to the challenge

Action and prerequisite

A mechanism for open innovation which ensures that the interests of SMEs and industry are also protected so that they will participate in such programmes.

Success criteria

Achievement of the priority actions at the level of:

- Creation and validation of new products for the applications identified above.
- Effectiveness of partnerships in terms of type of achievement and time.
- A mechanism for providing recognition and reward at all levels in multi-party R&D consortia.

Research

A body of essential knowledge built with consideration of use and contribution to theory (Pasteur's Quadrant) through a collaborative and coordinated process joining the value chain from scientific discovery to application and product development and utilization for improved preventive and therapeutic interventions. The process demonstrates an impact on health and the ecosystem of health research, generating new research questions and economic value.

Innovation

New ways of getting multiple industry actors and SMEs to collaborate openly with academia so that results are shared and leads are rapidly identified and taken forward – new collaborative designs for mixed research campuses involving academia and industry in joint research and shared benefits. Encouragement of further development and penetration of pre-competitive collaboration models for R&D. Potential of synthetic and systems biology and the convergence of disciplines to accelerate the development of new products. Potential of improved production technologies and technology platforms (e.g. improved, high yield culture systems) to reduce production infrastructure footprint and costs.

Economy

The cost of new anti-infectives (such as anti-HCV treatments) is beyond the reach of many struggling health care systems and is a drain on the economy. Concerted push and pull mechanisms to ensure that the price of resulting products is not inhibitory to access will need to be established. In addition and combined, savings from new technological approaches (simpler, more reliable, faster, smaller, in some cases more accessible) need to be tested and scaled up to push down costs and prices if evasion mechanisms are discouraged. In addition, new technological approaches (simpler, more reliable, more accessible, more effective) can potentially push down costs and prices if appropriate marketing mechanisms are put in place.

Health care and public health context

Anti-infectives are essential for controlling infection, but much more is needed. It is critical to assess infectious disease within the broader health context to determine which integrated approaches entail the most effective mix of curative and preventive strategies that can be deployed effectively in a given health and social system, meeting public acceptance and in line with public health policies and strategies. To meet public health needs, solutions should be adaptable to varied technology and resource settings, within Europe and beyond. Research collaborations for public health infectious priorities should be based on strong partnerships across different cultures and systems to yield maximal utility and to contribute to the establishment of a research ecosystem of wider reach and benefit.

Internationalization and collaboration

Infectious diseases are by their nature international travellers, and global population dynamics have greatly increased over the past decades. Therefore, broad and effective international collaboration is essential for a comprehensive understanding of the behaviour and variation of the infectious agent, and the range of potential impacts in humans and animals. Diseases which have not yet appeared in a country may yet be introduced, and scientific preparedness for response and control must draw on the findings of research conducted in endemic regions. Collaborative research with an eye to affordable and durable solutions serves not only development objectives but, equally important, scientific and societal self-interest.

Risks

What are the risks and how can they be minimized or avoided?

New treatments may be over-used resulting in rapid resistance, or be too expensive, as might be other new products, including vaccines and diagnostics. This will require policy and strategy commitments to encourage and incentivize appropriate use, and to support access. Anti-vaccine lobbies may generate public fears or rejection of new vaccines.

Bottlenecks

Bottlenecks in addressing these areas, inherent risks and uncertainties, and options to mitigate them

Intellectual property and business interest, if not managed appropriately, can become very serious bottlenecks. Achieving the desired outcomes will require real-time sharing of data between all partners (industry, SMEs, academia, and public sector agencies). An innovation model will be required enabling collaboration while providing business interest. Pre-competition collaborative models are one pathway to be further developed, but later-stage approaches must also be conceived, tested and developed.

The costs of product development, in particular late-stage clinical trials, are bottlenecks. Improved down selection through better understanding of animal models, pk/pd-modelling, innovative bioinformatics, and analytical approaches using big data and genetics will assist in reaching development decisions earlier (the concept of “kill early”). As a consequence, it should be possible to develop and establish more adaptive clinical trial designs.

Science and technology, markets, policy gaps and potential game changers, including the role of the public sector in accelerating changes

A coherent R&D approach based on (i) the priorities mentioned above and with (ii) the principles of partnership/collaboration outlined, will help overcome the gaps in the areas of (i) basic knowledge, (ii) implementation arrangements of the R&D process, (iii) procedures and speed of validation (clinical trials up to phase 4) and (iv) the translation to policies and strategies to introduce the new products effectively, (v) data and access.

Game changers

Weak and fragmented translational research capacity in Europe has been a bottleneck to translating innovative ideas into products. The strengthening of existing science parks and the creation of new environments for academia, SMEs and industry to collaborate closely will facilitate leverage of private capital to translate public-sector research into anti-infectives, vaccines, other health products and interventions. Within such collaborations positive determinants include broadly acceptable IP solutions which allow for preservation of value and for access in line with need, integrated therapeutic approaches which could not be overcome by mutations conferring resistance in the pathogen as well as therapeutic vaccines to resolve major chronic infections, and preventive vaccines for priority diseases.

Role of the public sector

The public sector is inextricably involved in research and development for infectious diseases: in identifying the problems through surveillance and response to health events within a given health and social system and in contributing to many aspects of health care or public health in countries. The public sector is thus a contributor, user and a provider of solutions and

interventions. It can, and does, affect research outcomes by defining infectious disease control and elimination priorities and needs, generation of research questions and active participation in research consortia. It can promote policies and strategies to ensure effective application of research findings and products, and in more affluent countries through public funding of research and incentivizing cooperation and inclusion of the private sector. Regulatory agencies have the responsibility to develop new standards to assess benefits and risks of novel regulated health products. European regulatory agencies are acknowledged world leaders in this context.

Areas with the strongest potential to leverage the EU knowledge base for innovation and, in particular, ensure the participation of industry and SMEs

Key areas for industry and SMEs in addressing this particular challenge are many, as listed below:

- Participation in mixed campuses to leverage academic innovation and industry pull.
- Access to product libraries and high-throughput screening tests.
- Design and construction of meta-databases to manage data from gene arrays, preclinical and clinical studies, and to link these results to bioinformatics and other data analysis modalities.
- Development and establishment of effective platform technologies – e.g. vaccine platforms such as adjuvants and vectors, chimeric backbones, diagnostic platforms.
- Exploration, promotion, development and validation of new technological approaches such as synthetic biology, which may facilitate greater (and easier) creativity in innovation.
- Participation in scientific collaborations to assess proposed new tools, standards, and approaches that address the safety, efficacy, quality, and performance of medicines, vaccines and diagnostics.
- Contribution to designed collaborations with academia and the public sector from initiation through the research, development and application cycle.

Strong areas to support integrated activities for each of the big challenges

Rising costs, rising health care expectations, and economic constraints conspire to reinforce demands for focused and productive research investments. Complex biomedical/social/environmental problems such as infectious diseases require well-planned multidisciplinary and multisectoral research to generate solutions which will be acceptable and effective in real life, and will be suited to counter the highly mutable microbial world, and support public and global health needs in all contexts.

The ways in which patterns of regulatory and licensing constraints have been shown to have a major impact on industry R&D choices indicates a role for enhanced attention to regulatory science. Expectations will grow to reduce regulatory and policy burden while, at the same time, expectations for more transparency about the quality of products and health technologies will increase. New norms and standards will need to reflect these aspirations but not to the point where quality suffers. Convergence, internationally, of norms and standards will be increasingly recognized as one key driver to address these challenges.

SWOT analysis

<p>Strengths</p> <p>New technologies – reverse vaccinology, gene manipulation, synthetic biology, bioinformatics, genomics, proteomics, all the omics.</p> <p>Health care expectations are high, so new products and interventions are often sought and welcomed. Large knowledge base exists.</p>	<p>Weaknesses</p> <p>Little progress in recent years despite investment.</p> <p>Industry reticence due to high risk low return.</p> <p>Much of large knowledge base not fully accessible.</p> <p>Outdated and maladapted approaches to R&D slow down the research pipeline and impede the coordinated and coherent application of research outcomes.</p> <p>Cross-sectoral collaboration as a routine still not the norm.</p>
<p>Opportunities</p> <p>Emerging threats with potential very high morbidity, industry academia collaboration, long term effects of chronic and occult infections, growing acceptance of ‘One Health’ concepts and impacts.</p> <p>New appreciation of connections between infection and chronic disease states and cancer.</p>	<p>Threats</p> <p>IP issues and patent “thickets”, uncontrolled use of new drugs, public resistance to vaccines, breakdown of health systems following financial downturn.</p> <p>Failure to build capacity and trust across stakeholder groups has led to distrust and resistance to “follow orders”. Concerted public engagement with outreach/educational campaigns to explain information and empower individuals based on informed-decision making, as opposed to the current very hierarchical model which fails to empower the individual.</p> <p>Persistence of a ‘publish or perish’ research culture despite reductions in research spending encourages competitive rather than collaborative research.</p> <p>Opportunities to look at how information is disseminated and its impact.</p>

Key references

Antimicrobial resistance: global report on surveillance 2014

<http://www.who.int/drugresistance/documents/surveillancereport/en/>

Birkett AJ, Moorthy VS, Loucq C, Chitnis CE & Kaslow DC (2013). Malaria vaccine R&D in the Decade of Vaccines: breakthroughs, challenges and opportunities. *Vaccine* **18**;31 Suppl 2: B233–43.

Chong DL & Sriskandan S (2011). Pro-inflammatory mechanisms in sepsis. *Contrib Microbiol.* **17**: 86–107.

Delany I, Rappuoli R & De Gregorio E (2014). Vaccines for the 21st century. *EMBO Mol Med.* **6**: 708–720.

Establishing Precompetitive Collaborations to Stimulate Genomics-Driven Drug Development: Workshop Summary. Washington, DC: The National Academies Press, 2011.

Gaynes R & Edwards JR (2005). Overview of nosocomial infections caused by gram-negative bacilli. *Clin Infect Dis.* **41**(6): 848–54.

Graham BS (2013). Advances in antiviral vaccine development. *Immunol Rev.* **255**(1): 230–42.

Haeusler GM & Slavin MA (2012). Complications of sepsis: the role of risk prediction rules, biomarkers and host genetics. *Expert Rev Anti Infect Ther.* **10**(7): 733–5.

Kairalla JA, Coffey CS, Thomann MA & Muller KE (2012). Adaptive trial designs: a review of barriers and opportunities. *Trials.* **13**: 145.

Stokes DE, *Pasteur's Quadrant – Basic Science and Technological Innovation*, Brookings Institution Press, 1997.

Wicker S & Maltezou HC (2014). Vaccine-preventable diseases in Europe: where do we stand? *Expert Rev Vaccines* **24**:1–9.

7.6 Working group report: Early development

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What is the challenge?

Early development refers to the central importance of the science of childhood mental and physical health and disorder, for understanding the factors and processes that shape the life course from cradle to grave.

The challenge of “Early development” is to generate new knowledge grounded in normal developmental processes, highlighting the value of viewing mental and physical ill-health as an aberration of normal development, and implement this knowledge for prevention and intervention in child care, public health and social care service.

The challenge of early development has four key levels; identify trajectories across the lifespan and demonstrate mechanisms of continuity and discontinuity; explore resilience as natural protection; examine the role of genetic, biological and environmental influences across different periods of development; and assess the benefit of early interventions for later health and wellbeing.

Discovery and delivery research of pathways and interventions can lead to optimal development, increase resilience and mitigate the impact of biological, psychosocial and environmental risk factors. A life course perspective is needed for addressing mental health and wellbeing from childhood to older ages. There is huge heterogeneity among children in their response to the same adversity, stress and trauma. Some children are more susceptible to both negative and positive influences. Consequently, we need research examining which protective processes and adaptive systems make a difference in children’s lives and change the environment for the better. Variations in the expression of vulnerability for disorders across age and gender are striking. This has to be taken into consideration when designing prevention and implementing interventions.

Why is this a challenge?

Recent discussions to reduce the soaring cost of adult mental and physical illness have emphasized not only reducing worsening of conditions of those already ill, but preventing and delaying its onset. Tracking the effects of early risk factors and delineating the causal mediating mechanisms that contribute to a long-term sequela, will have profound implications for early intervention programmes. New tools, such as diagnostics, ICT and robotics can provide effective treatment and prevention. Interdisciplinary research can drive forward research in neuroscience, biology, genetics and the interaction with psychosocial and environmental factors for better understanding of the development of mental disorders. Research that starts in pregnancy is needed for understanding how lifestyle factors, quality of family relationships and societies can contribute to high quality care for the children and at the same time facilitate equal opportunities for the parents for employment and career. Data in huge longitudinal studies with research biobanks, national registries and archival data represent a resource for research in early development. Children are the best informants about

their own health and wellbeing and pose a challenge for efficient data collection while upholding high research ethical standards.

Action/research needed

Research across the breadth of theoretical and empirical approaches in early development is needed for:

- Understanding the multifactorial causes affecting the developmental pathways of mental and physical health and wellbeing across different age groups.
- Translating scientific knowledge into clinical practice and early interventions that are effective, but also affordable and achievable.

Early development should be demonstrated in application in developmental psychopathology, observational epidemiology, genetics and environmental relationships, and neuroscience for identifying root causes of continuity or discontinuity of mental and physical ill-health. Instead of focusing only on what goes wrong, account should be taken of resilience for efficient prevention and intervention. The role of psychosocial factors and the physical outdoor environment should not be underestimated when implementing prevention and intervention.

Concrete recommendations for the research programme (short, precise, and operational): where the science should go

- Life course trajectories: the role of causal mechanisms in the onset, persistence, escalation or offset of mental and physical ill-health.
- Resilience: the relationship between resilience and mental and physical health, across gender and age groups.
- Genes and behaviour: understanding the environmental determinants of the phenotype in a developmental perspective.
- The developing brain: explore the neurodevelopmental origins of normal and altered social cognition and behaviour.
- Prevention and intervention: translate knowledge from resilience in early development into impacts for children in low- and middle-income countries.

Many European countries and Canada and the US have present data from huge longitudinal, population-based cohort studies starting in pregnancy and early childhood. Support is needed to keep studies going, encompassing longer periods of the life span. For example, effects of interventions in pregnancy or early childhood can be evident decades later in the child's life. Research biobanks and national health and social registries represent another wealth of health-related information. These data are valuable for all types of non-experimental research. In addition, experimental research is needed to understand early development and should be encouraged. ICT tools can provide new parameters. Studies gathering information from the child her/himself, parents/caregivers, siblings, peers and teachers are needed. Studies adding the potential value of the green environment should be supported. The green physical outdoor context might have therapeutic effects not yet discovered. Research covering factors related to genes, individual characteristics, family lifestyle and the outdoor context will give a richer understanding of human life course development. Multiple methods are necessary when collecting data, including for example biomarkers, tests, surveys, observations, interviews,

experiments, and so on. In addition, ICT tools and modern technology are important parameters because children integrate online and mobile technologies into their daily life. Social physics is a new approach illustrating creative interdisciplinary activities. Combining psychological knowledge about social group dynamics and decision making and physics improves predictive skills.

Innovation needed in relation to the challenge

Action

Clinicians, other professionals and researchers concerned with children's health and wellbeing need to work in collaboration with the children themselves, care-givers, teachers and clinicians. When implementing early interventions, active interest the public and communities is crucial. When piloting early interventions and randomized clinical trials with children and care-givers, it is essential to obtain ethical approval because intervention can have both positive and negative effects.

Products

Children represent a challenge to the development of age-appropriate products. Age-appropriate adaptations are needed for research methods, diagnostic kits, ICT tools, contents of interventions, stimulating toys and indoor and outdoor equipment for group care. Children grow up with online communication, smart phones and social networking and in this context we can foresee new technological products for data collection, disease detection, prevention and treatment.

Success criteria

- Research – new knowledge of the significance of early development for life span development. Adverse events and risk experiences that occur in pregnancy and the first years of life can produce physiological and psychological disruption that can have lifelong consequences. Models integrating different levels, including brain, genetic, epigenetic, phenotypic, family life style, social networks and the cultural context, give improved understanding of the developing human being.
- Innovation – discovery of new biomarkers/diagnostics, quality parameters for harmonious parenting and stimulating environment in kindergarten/school contexts. ICT, robotics and tools for treatment can enrich the environment at an early stage in development for children with special needs.
- Economy – high quality interventions in kindergarten can prevent adult diseases. Return on investment in human capital is more effective the earlier in life the money is spent.
- Health care – most children are happy and healthy. Active engagement in public health and local communities to include children with special needs and minority children in early group care can lead to resilience and improved readiness for school.
- Public health – a stronger economic workforce and economic competitiveness as a result of improvement in mental and somatic health of children. Decrease in incidences of non-communicable diseases through environmental interventions,

Internationalization and collaboration

The lives of the poorest have improved more rapidly during recent last decades. We need research from many countries to collaborate in examining early development within a global context. We need to understand which resilience processes can be identified among children in low- and middle-income countries. In addition to existing international initiatives in research on large longitudinal cohort studies, registers, biobanks and clinical trials, there is a challenge to conduct research into physical/mental comorbidity and consider outcomes beyond symptom measures. The EU can play a role in supporting research that takes into consideration the fact that children grow up in different cultures and within various types of social contexts and values. The social and physical environment is a central issue when implementing new findings. Research identifying protective factors for healthy development can open new business opportunities for EU companies.

Bottlenecks

Where are the bottlenecks and how can they be alleviated?

Early development is a huge discipline with many “silos” in the health and social care system. There is lack of integration of between the medical tradition and the psychological and social sciences. Research in early development needs active support from key stakeholders and a raising of awareness of mental and somatic health issues among children, as well as for all age groups across the life span.

Risks

What are the risks and how can they be minimized or avoided?

Research in both small targeted groups and large population-based groups is expensive. Research targeting at-risk children (children at risk of disturbed development, NCD, etc.) is obviously needed because children cannot wait for help or the development of knowledge about causal mechanism of disorders, and the building of efficient treatment and prevention programmes. Large, population-based, prospective longitudinal cohort studies should also be supported. They can really contribute to understanding the factors that shape mental and somatic health and disorders across the life span. Both approaches are needed. Research ethics in studies of early development is a challenge because it involves children. This should be adequately addressed and in many circumstances the child is the only and best informant.

Gaps

Where are the gaps and how can they be closed?

- While the life span perspective is fundamental for human beings, it is difficult for researchers to get funding for life span studies covering more than five years. More success stories are needed from “research generations” (young research generations taking over senior generation research projects) that teach us about normal and abnormal lifelong development through the life course.
- EU countries have different social politics and different risk factors, which need to be considered in research. For example, when generalizing findings about mechanisms and causal effects, the social context and cultural setting should be considered before attempting to implement the findings. Risk factors tend to cluster and more knowledge

is needed to understanding how various risk factors impinge upon early development and shape life span development. One solution is to track the effects of any specific early risk factor and delineate the mediating mechanism that contribute to a long term sequela of early adversity in a social context.

- Interventions are needed because children cannot wait. However, evidence indicates the highest net benefit comes from the longest follow-up studies. Joining up of existing longitudinal studies and databanks where individuals have been followed for long periods should be supported.
- For far too long behaviour genetics and socialization theory have been a stage for dispute. The working and functioning of the brain, body and mind in human development will be shaped by both genes and environment across the life span. There is a need for gene–environment studies examining how nature and nurture interact to shape development through the life span.
- The rapid growth of ICT tools transforms the lives of most people, especially in low- and middle-income countries. There is scarce knowledge about how this can be utilized for diagnoses, training and intervention.

Game changers

What are the game changers that would significantly help to meet this challenge and how can they be developed and implemented?

Investment in early years for gain in adolescence, early adulthood and older age can bring enormous benefits for health, happiness and the economy. A game changer will be when the public support early interventions over later repair. Early investment in children can prevent mental, somatic and social problems and hence reduce the risk of school failure and drop-out. An increased focus on positive psychology, resilience and protective factors can give hope to the public and improve quality of life.

Role of the public sector

What is the public sector's role and how can it best be implemented?

The role of the public sector (communities, cities, universities, hospitals, research institutes) is to acknowledge the huge heterogeneity among children. In all EU countries, there are minority families with children. Cultural values impact on and shape individual life span development. The public sector may also have a key role in early piloting with inclusion of minorities and gender equity. The public sector may play a key role in the social context for interventions and studies. Problems for researcher to get access to potential research participants and collect data in public institutions, kindergarten and schools should be solved.

Strong areas for industry and SMEs

Bottom-up activities

Early development and life span research offers an option for development of products related to ICT, diagnostics, smart devices, toys, wearable technologies, telemedicine and web-based assistance.

Industrial roadmap

Understanding human behaviour and lifelong human development can help the industry to understand and to come closer to the market. The social context is important for those who use ICT and tools. A dentist's and physician's office for children are examples of SMEs which need appropriate ICT and tools. Design and construction of databases that manage data from gene arrays and clinical information to register data.

Strong areas to support integrated activities for each of the big challenges

Social science and the humanities

Understanding how life span development unfolds in context requires collaboration with the humanities. Findings need differentiated interpretations depending on the specific context in which men and women live and children grow up.

Responsible research and innovation, including gender aspects

Research in early development with children necessitates addressing high research ethical standards, but at the same time stimulates innovative approaches in cutting edge research. Gender makes a difference during the various decades across the life span. Therefore, gender analyses, both between genders and within each gender, should be encouraged.

Climate and sustainable development

Daily access to green outdoor physical environments can play an important role in reducing obesity and symptoms of mental health disorders. Examining how social environments and green surroundings are appreciated enables researchers to go beyond simply measuring neighbourhood structure, to include the influences of genes, individual characteristics and family functioning and social nuances.

Interdisciplinary activities

Complex biological, psychological, physical, social and environmental problems require multidisciplinary teams.

SWOT analysis

<p>Strengths</p> <p>At-risk children cannot wait.</p> <p>Longitudinal prospective cohort studies.</p> <p>Resilience research conveys hope and not only adversity.</p> <p>Investing in early interventions reduce adult disease and disorders and returns more money than it costs.</p>	<p>Weaknesses</p> <p>Difficult to develop efficient contents of prevention and intervention programmes.</p> <p>Successful programmes tend to be costly due to a lack of interdisciplinary, collaborative approach rather than a given.</p> <p>Longitudinal studies tend to be too short.</p>
<p>Opportunities</p> <p>Need for integrating medical and psychological research.</p> <p>Need for a greater recognition for understanding early development.</p> <p>Need for changing investment in post-school age to pre-school age.</p> <p>Need for implementing new causal findings into programmes.</p>	<p>Threats</p> <p>Inadequate account of social context and cultural differences when generalizing findings.</p> <p>Research ethics in early development studies can pose restrictions on cutting edge research.</p> <p>Interventions can have both negative and positive effects.</p>

Key References

- Bekkhuis, M., Rutter, M., Maughan, B. & Borge, A.I.H. (2011). The effects of group daycare in the context of paid maternal leave and high quality provision. *European Journal of Developmental Psychology* **8**, 6: 681–696.
- Belsky, J. & Pluess, M. (2009). Beyond the diathesis-stress: Differential susceptibility to environmental influences. *Psychological Bulletin* **135**, 6: 885–908.
- Brendgen, M., Boivin, M., Vitaro, F., Girard, A., Dionne, G. & Pérusse, D. (2008). Gene-environment interaction between peer victimization and child aggression. *Development and Psychopathology* **20**, 2: 455–471, doi: 10.1017/S0954579408000229.
- Campbell, F., Conti, G., Heckman, J.J., Moon, S.H., Pinto, E., Pungello, E. & Pan, Y. (2014). Early childhood investments substantially boost adult health. *Science* **343**: 1478–1485.
- Del Maestro, M., Cecchi, F., Serio, S.M., Laschi, C. & Dario, P. (2011). Sensing device for measuring infant’s grasping actions. *Sensors and Actuators. A Physical* **165**: 155–163.
- Lancet: The Lancet Commissions: Global Governance of Health: The Lancet-University of Oslo Commission of Global Governance for health. The political origins of health inequity: prospects for change. Online: February, 11, 2014.
- Masten, A. (2014). Global perspectives on resilience in children and youth. *Child Development* **85**,1: 6–20.
- New York Academy of Science (2007). *Resilience in Children*. Vol. 1094.
- Nithianantharajah, J. & Hannan, A.J. (2006). Enriched environments, experience-dependent plasticity and disorders of the nervous system. *Nature Reviews Neuroscience* **7**: 696–709.
- Ogders, C. L., Moffitt, T.E., Tach, L.M, Sampson, R.J., Taylor, A, Matthews, C.L. & Caspi, A, (2009). The protective effects of neighbourhood collective efficiency on British children growing up in deprivation: a developmental analyses. *Developmental Psychology* **45**, 4: 942–957.
- Rutter, M, (2006). Genes and Behavior. Nature–Nurture interplay explained. *Blackwell Publishing*.
- Scassellati, B., Admoni, H. & Mataric, M. (2012). Robots for use in autism research. *Annual Review of Biomedical Engineering* **14**: 275–294.

Vitaro, F., Brendgen, M., Boivin, M., Cantin, S., Dionne, G., Trembaly, R.E. & Pérusse, D. (2011). A monozygotic twin difference study of friends' aggression and children's adjustment problems. *Child Development* **82**, 2: 617–632. doi: 10.1111/j.1467-8624.2010.01570.x.

Walker, S.P., Wachs, T.D., Grantham-McGregor, S., Blac, M.M., Nelson, C.A., Huffman, S.I. *et al.* (2011). Inequality in early childhood: risk and protective factors for early child development. *Lancet* **378**: 1335–1338.

7.7 Working group report: Sustainable health and care systems

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Introduction

Patients, their families and their communities in Europe are not getting the care they need and desire. This is especially so for patients with chronic diseases or elderly people. This is not due to lack of clinical knowledge, since the last decades have seen vast biomedical clinical improvements and this will continue. Where we are failing patients and citizens is in the fields of quality, i.e. the systematic, transparent and unbiased identification of the best care models and organizations’ capabilities, new approaches for patient engagement, costs, sustainability, and outcomes. “Tweaking” around the edges of health care systems will not deliver better care at the scale necessary. This will require being able to provide better health and preventive care at lower cost.

Consequently more ambitious and comprehensive health care reforms are required and new research is required to close to the numerous existing gaps. Furthermore, new clinical diagnostics, treatments and other innovations including in the field of ICT will not become embedded into mainstream health care unless we also focus on research in these areas.

Progress is being made on several fronts. New approaches are emerging and are being implemented in countries. Best practices are appearing and they require comparative research. Some are organizational, some are processes which give more voice and choice to patients, some are technological. Major improvements in information technology and communication over the past decade have created tremendous opportunities to strengthen health systems. Electronic Medical Records, bringing together patients’ clinical, diagnostic and prescription information in one place, have greatly improved patient care and monitoring, as well as the coordination and accuracy of this information. Health Management Information Systems, increasingly incorporating real time data, allow managers and policy-makers to monitor processes and outcomes, enabling greater efficiency, effectiveness and improvements in the quality of care. By reminding patients to take medication on time or monitoring vital signs such as pulse and blood pressure among heart patients, innovations such as “mhealth” (using mobile apps) and ehealth (using other forms of electronic technology) both enable significant cost savings and create the potential for innovative services and start-ups (European Commission, 2014).

In addition to providing opportunities to purchasers and providers of care, access to information has greatly empowered patients, their families, their communities and their health care providers to serve as co-producers of their own care. A large number of websites (including UK National Health Service [NHS] Choices, HealthFinder.gov and NIH’s MedLinePlus in Spanish) provide a wealth of information on the signs and symptoms, and treatment options available (West, 2011). Online clinics such as those hosted by the NHS allow patients to get answers to specific medical issues from nurses, specialists and other clinicians without patients having to leave their homes. Finally, social networks have allowed patients, their families and their health care providers to share information, and have led to the creation of virtual communities and support groups, particularly focusing on chronic

conditions. West (2011) cites the example of a network of 23,000 patients established by the firm PatientsLikeMe who share and exchange information on a set of major chronic diseases, including HIV/AIDS, multiple sclerosis, Parkinson's disease, and mood disorders.

What is the challenge?

The improvements mentioned above imply the enormous potential for a broad transformation of preventive and clinical health care. This in turn implies encouraging research into population health, since many of the health challenges of today (such as chronic conditions) will not be resolved by an exclusive focus on clinical interventions, but rather by upstream interventions with a focus on prevention and broader public health including environmental factors.

These opportunities bring with them significant challenges. There are already huge datasets available, but many are not targeted to these new research needs or are not available for research and other purposes. For example, as we move towards more integrated care systems we do not have the right data to measure the impacts of provider integration, the data required to drive towards population health, nor the data required to measure the impact of ICT technological innovations. In other words, data gaps impede the analysis of quality of care, new organizational structures, staff engagement and training, efficiency and sustainability opportunities, and new health care payment schemes.

The capacity to store, process and analyse large volumes of data, also termed “big data”, has improved significantly over the last few years. However, the truly effective management of the rapidly increasing quantity of these data (including its analysis and interpretation as well as the application of these findings into practice and policy) is a major area that needs to be addressed. In the absence of this, opportunities for potential efficiency gains and quality improvement will remain unidentified. The “big-data revolution in health care” (McKinsey, 2013) is a “game-changer” that offers many opportunities to address these challenges. Concurrently, the active involvement of patients in their own care has brought to the fore the need to create health systems that (in line with goals laid out by WHO) are transparent and responsive to user needs and demands, including those raised by patient associations and advocacy groups, yet also respect individual confidentiality and other ethical issues (AHPSR, 2009).

The EU, like many other world regions, is predicted to face substantive deficits in the availability, accessibility, acceptability, motivation and quality of the health workforce in the next 10–20 years. Anticipating the deficits, with particular emphasis on urban/rural disaggregation within countries, will be essential to inform EU, national and sub-national policy. Reducing projected deficits must focus on the opportunities to develop a fit-for-purpose health workforce for the 21st century, a workforce that is able to anticipate and respond to demographic and epidemiological transitions, and be flexible and adaptive to innovation.

There is a huge leadership challenge behind these changes. Past leadership approaches are probably not appropriate for these broader transformations. Policy makers, managers and clinicians have known for decades that we need to find a better balance between research on upstream and downstream factors. This change has been impeded by a lack of some of the necessary tools (e.g. ICT and integration tools), as well as insufficient political commitment. Better population health will not happen without responsible leadership (Bassi and McMurrer – HBR 2007).

Peripheral to the above-mentioned challenge, the EU will have a unique time-limited opportunity to significantly improve public health through generating research-informed evidence to influence global policy on illicit drug use.

Why is this a challenge?

The potential quality and efficiency gains that can result from addressing this challenge are significant. Big-data-informed practice and policy will result in better management and organizational practices leading to improved quality of care, reflected in important health and wellbeing challenges such as the control of nosocomial (hospital acquired) and environmental infections and the elimination of needless expensive diagnostic tests.

For instance, ensuring data exchange across medical facilities and encouraging the use of Electronic Medical Records, has enabled the Kaiser Permanente group in the United States to save an estimated US\$1 billion from excess consultations and lab tests, and improved cardiovascular disease outcomes (McKinsey, 2013). Greater use of real-time data will allow managers and policy makers to rapidly detect and address quality issues and inefficiencies as and when they arise instead of waiting for quarterly or annual reports. Similarly, research to improve the responsiveness of the health system could result in improvements in patient waiting times and the enhancement of patient choices, leading to increased public satisfaction, which is one of the goals of all health systems.

Another challenge is to use this new technology and these big data systems to ultimately focus on prevention and proactive health care aimed at wellbeing, rather than purely on treatment after preventable illnesses have occurred. This requires improved coordination between public health, social services and health care delivery. In addition, there is an opportunity for the health sector (including public health and social services) to serve as a model of best practice and innovation in the area of environmental sustainability, so important in the face of globally dwindling resources and climate change.

Europe expects a deficit of at least one million health workers by 2020. The deficit will impact the availability and quality of health services and will be most acute in rural populations. Disaggregated data on the availability, accessibility, acceptability and quality of health workers will be essential to determine areas of greatest need and inform local solutions. EU scientific expertise in Geographical Information Systems (GIS) provides an opportunity to map access to health workers and health services and determine areas of greatest need.

Action/research needed and research products expected

There is a great need and priority to conduct innovative strategic research to enable the integration of big data in day-to-day health care management and delivery.

Research and evaluation (including cost-benefit) are also needed urgently on demand side concerns, including but not limited to: health-seeking behaviour; individual patient and citizen satisfaction; attitudes and behaviours in mHealth and eHealth; the training and use of new technologies by health care providers and users; and the integration of health associations' and civil society's needs in health decision-making processes. Consideration of demand-side concerns in an iterative fashion will contribute to more responsive and people-centred health systems in the European Union.

Making health systems more responsive necessitates research on developing measures of patient and health care provider satisfaction using qualitative and mixed methods, and

generating indicators that reflect the needs and concerns of European citizens and the EU directorate for health and consumers. This “needs-based approach” will bring us closer to the key organizational target around population health.

Implementation research and the uptake of research evidence and its translation to innovation are other areas that demand greater study with the need for the identification of effective strategies to both disseminate and catalyse demand for research evidence among practitioners and policy makers. Implementation research can address or explore any aspect of implementation, including the contextual factors, the processes of implementation themselves, and the outcomes or end-products of the implementation. For example, the EU already supports the IMPLEMENT project. This project will provide a research agenda on “Implementation of chronic care improvements”. It is being designed at present and is expected to deliver a list of research priorities for faster implementation of chronic care improvements. It will complement the Horizon 2020 Sustainable Health Systems Challenge.

Research areas in support of ensuring that the workforce will be able to anticipate and respond to demographic and epidemiological transitions focused on: the education, deployment and supervision of a health and social protection workforce; the health sector as a catalyst for job creation and economic growth; the geographical mapping of inequities in the availability, accessibility, acceptability and quality of the health workforce; inter-operable minimum data sets on all practicing health workers; and the potential for sustainability best practice and innovation in the health sector.

These ambitious transformations will not happen without changing the relations and interactions that health systems and health professionals have with the patients, their families and their communities. Research on patient experiences and ways of truly empowering and engaging patients in these transformations will be key in giving shape to better quality and improved costs.

Addressing these challenges will need significant research in a number of areas. As highlighted by Gary King of Harvard, improvements in statistical and computational methods have greatly facilitated faster analysis; more research is needed in this area to effectively analyse exponentially growing data sets. Also, research must enable the more effective interpretation of large volumes of data, including through new ways to visualize data and by linking data sets, enabling the creation of new insights (Harvard Magazine, 2014).

Related to this is research in political science and other social sciences. Politics and ideology affect the way research and evidence is used. Understanding the politics of the decision-making processes is a key research area.

Creating truly sustainable health and care systems requires the creation of a continuously learning health care system, or a “system that learns, in real time and with new tools, how to better manage problems” (Institutes of Medicine, 2012). A learning health system is one that uses real time access to knowledge to continuously gather, process, and provide the best possible evidence to improve the quality of decision-making and patient care. It is centred on patient needs and perspectives, envisioning engaged, empowered patients; and includes patients, family members, health care providers, and other care-givers as part of the continuous learning team. A learning health system incentivizes high-value care, the reduction of waste and continuous improvement, and promotes transparent procedures to monitor safety, quality, costs, and outcomes. It is enabled by leadership that is committed to working together to support continuous learning as a central aim of the system, and uses a wide variety of methods (including team training and systems analysis) to ensure continuous learning and systems development. There is a need for best practice examples which have been appropriately evaluated, and which are scalable and transferable. The human and material

costs of not creating a learning health care system are enormous, with one study estimating that in the US alone, 75,000 deaths could have been prevented and US\$ 750 billion saved in a calendar year if every state had performed as well as the best performing state in health care delivery (Institutes of Medicine, 2012).

Key assumptions

One of the key assumptions of learning health systems is the adaptation of systemic decision-making processes to ensure continuing improvements in health systems performance. Performance assessment and monitoring provides an important basis for analysing the outcome and impact of different interventions, and, more generally, population health status (Roberts *et al.*, 2003). Learning health systems enable performance enhancements in health services and programmes, for instance improved monitoring of medication and identifying at-risk populations in time to prevent rather than treat illness, thus contributing to improvements in structural and process quality of care provided to patients (Donnabedian, 2005). In turn, enhanced quality of care will lead to improvements in health status and public satisfaction, which are among the ultimate goals of health systems. Health systems performance should take into account criteria such as sustainability, accessibility, equity and efficiency. In this sense, learning health systems will enable better allocation of resources, hence fostering continuity and sustainability of health care practices and systems in the EU.

Success criteria

Success in this area will involve the continuous analysis and interpretation of real time data, and the rapid incorporation of the evidence into practice and policy to improve quality and reduce waste. The health system will systematically engage with patients and care givers and communities, innovate to meet their expectations, and become increasingly responsive to their needs. It will be characterized by transparent procedures to monitor public safety, quality, costs, efficiency gains and outcomes, and be led by individuals committed to working together to support continuous learning through diverse approaches including team training and systems analysis.

Internationalization and collaboration

There are significant opportunities for international learning and collaboration within this area. Among these are understanding strategies that have enabled big data to inform practice and policy in other settings. There is much to be learnt from both low- and middle-income settings on the use of participatory research methods that can play a major role in the development of indicators of patient satisfaction as well as ensuring sustainability through breaking down traditional barriers to access, equitable delivery of health and wellbeing, and innovation in the use of renewable energy/materials and other sustainability practices.

Bottlenecks in addressing these areas, inherent risks and uncertainties, and options to address them

Bottlenecks

If health systems are to derive benefits from the “big data revolution,” mechanisms have to be developed to integrate, analyse, interpret and translate data into practice and policy in a timely fashion, while respecting ethics and confidentiality. Although the doubling of computing

power every 18 months (Moore's Law) provides for increased technical capacity, abilities of human resources for health also need to be strengthened concurrently. Building the capacity of researchers, practitioners and users/patients to capitalize on the quantity, quality and timeliness of data represents a paramount challenge to learning health systems. Another challenge lies in the methodology to measure and assess performance, the quality of care, and patient satisfaction. In this regard, definition of indicators and targets also remains equivocal. Another bottleneck is the dearth of collaboration between researchers and decision-makers to ensure evidence-based medicine and public health in the EU.

Furthermore, demand-side responsiveness will require learning health systems to deal with contradictory requests and competing interests. An example of particular relevance to the European Commission is the pharmaceutical lobby for enhanced intellectual property rights protection enshrined in the Transatlantic Trade and Investment Partnership (TTIP) vs. consumer and civil society advocacy towards prompt access to inexpensive generic medicines.

Alleviating bottlenecks

Efforts have to live up to the size of the challenges inherent in the creation of learning health systems. In essence, training and strengthening capacities of human resources for health should remain an essential priority. Learning health systems should also integrate new models of evidence application and uptake into practice and policy, taking into account the quality of scientific evidence. Health systems will thrive if they foster collaboration between researchers and decision-makers, and implement innovative research models such as embedded research led by decision-makers. Research embedded in the real world promotes the integration of scientific inquiry into the implementation problem-solving process, along with programmatic improvements in an iterative and continuous manner. Health systems should also use the full gamut of opportunities put forth by new information technologies to address this challenge (e.g. community of practices, online tools to measure patient and consumer satisfaction).

Furthermore we need rapid-cycle research in health care services (including social care and public health). The idea is to ensure that ineffective ideas "fail fast," while the successful innovations need to spread throughout Europe quickly.

Risk minimization

Possible caveats to the use of big data informing learning health systems include the under-recognition of its value and importance by decision-makers, health care practitioners, and users/patients. Privacy issues inherent to data transparency will also become an increasing concern. Although new computer programs can readily remove names and other personal information from records being transported into large databases, stakeholders across the industry must be vigilant and watch for potential problems as more information becomes public (McKinsey, 2013). Firewalls and confidentiality protection must be enforced in learning health systems to ensure privacy of patient information, while at the same time allowing for the free flow of information for the purposes of monitoring, research and innovation.

Science and technology, markets, policy gaps and potential game changers, including the role of the public sector in accelerating changes

Role of the public sector

The public sector has a vital role to play as a funder of cutting edge research in this area, a research regulator, a potential model of sustainable practice and innovation, and an owner of major big data. This is especially true of the EU where, given the amount of public sector funding, there are major potential efficiency gains for the public sector. Public investment could also enable new and emerging technologies such as mhealth and ehealth to adopt a holistic systems-level approach (as opposed to looking at single issues, as is usually the case), as well as joining up public health, social services and health care delivery systems. It will also be crucial in building capacity, including human capacity, to analyse and interpret data as well as to generate capacity among practitioners and policy makers to utilize evidence in decision-making processes. Finally, in its regulatory role, the government has a vital function in ensuring that legal and administrative measures to protect data privacy and ensure citizen rights to quality health care are in place and enforced.

Strong areas for industry and SMEs

The European Commission is a pioneer in bridging health systems and consumer interests not least through the political and societal engagements of the European Commission Directorate General for Health and Consumers. The EC has an important comparative advantage to lead the development of people-centred health systems, through the integration of patients' needs and consumers' satisfaction in the health systems' decision-making processes. For instance, the EC published recently a report on *Health Inequalities in the EU* (Marmot, 2013), confirming significant unmet needs and inequalities in health between and within EU Member States. In this regard, people-centred and learning health systems offer solutions to identify coverage gaps and tackle equity priorities locally and at larger scale in the region.

The big data revolution in health care also creates opportunities for innovative public-private developments applied to the health care sector (including social care and public health), including but not limited to start-ups on real time data management, delivery, and sustainable implementation.

Strong areas to support integrated activities

The US Institute of Medicine (IOM) framework on learning health systems integrates evidence from a wide array of scientific disciplines. Multidisciplinary research has the potential to yield improvements at various levels of the health system. Anthropology and ethnography and other qualitative approaches can provide insights on health-seeking behaviours (e.g. health status of migrants in the EU); and sociology can inform the learning capacity of institutions and complex health systems (e.g. Anthony Giddens' structuration theory to understand feedback loops in learning health systems; Giddens, 1984). Social psychology models should also be taken into consideration to better understand patient concerns and consumer habits.

Interdisciplinary methods and frameworks will be most useful to assess the organization of health care and to improve/enhance sustainable health system performance. In this sense, the humanities play an essential role in complementing technical input from medical engineering, molecular genetics, and computer science, for instance. Learning health systems will

enable/allow people to inform health care and prevention practices, and in turn health systems will inform and educate people to achieve better health and wellbeing.

SWOT analysis

<p>Strengths</p> <p>Real-time data and big data management have the potential to yield improved patient monitoring and quality of care.</p> <p>Health Management Information Systems allow managers and policy-makers to monitor processes and outcomes, enabling greater efficiency and effectiveness of health systems.</p> <p>Patients, families and communities have access to information allowing them to serve as engaged co-producers of their own care.</p>	<p>Weaknesses</p> <p>Underdeveloped systems to manage large volumes of data, including its analysis, interpretation and integration into practice and policy.</p> <p>Lack of standardized methodology to measure and assess performance, quality of care and patient satisfaction.</p> <p>Lack of integration between health and social care.</p> <p>Need for greater political commitment and leadership towards learning and responsive health systems.</p> <p>Weak population and environmental focus.</p>
<p>Opportunities</p> <p>Participatory medicine: learning and responsive health systems can foster patient engagement, leading to increased public satisfaction.</p> <p>New approaches to integrated care and population management are emerging.</p> <p>Business: innovative services and start-ups/spin-offs on real time data management.</p> <p>International collaboration and cross-learning opportunities in using big data to inform policy and practice.</p> <p>Collaborations across stakeholder groups including: the general public, policy-makers, government agencies, NGOs, research institutes, SMEs, students of all ages, alumni, the corporate sector, practitioners, funders and philanthropies.</p>	<p>Threats</p> <p>Competing and often contradictory interests (e.g. pharmaceutical lobby for enhanced IP rights protection vs. civil society advocacy towards access to generic medicines).</p> <p>Information and data produced are often not understandable for all stakeholders to make informed decisions.</p> <p>Threats to individual confidentiality and privacy of patient information.</p> <p>Misuse of data by vested commercial interests, e.g. for promoting unnecessary medical procedures or superfluous drugs.</p> <p>Lack of human resources in terms of mix and numbers.</p>

Key References

Alliance for Health Policy and Systems Research (2009). “Systems Thinking for Health Systems Strengthening” eds. De Savigny, D. and Adam, T. Geneva: WHO Press.

Barden-O’Fallon, J., G. Angeles, and A. Tsui (2006). Imbalances in the health labour force: an assessment using data from three national health facility surveys. *Health Policy Plan* **21**(2): 80–90.

Chen, L., T. Evans, S. Anand, J.I. Boufford, H. Brown, M. Chowdhury, M. Cueto, L. Dare, G. Dussault, G. Elzinga, E. Fee, D. Habte, P. Hanvoravongchai, M. Jacobs, C. Kurowski, S. Michael, A. Pablos-Mendez, N. Sewankambo, G. Solimano, B. Stilwell, A. de Waal, S. Wibulpolprasert (2004). Human resources for health: overcoming the crisis. *Lancet* **364** (9449): 1984–90.

- Donnabedian, A. (2005) Evaluating the Quality of Medical Care, *Milbank Q*, **83**(4): 691–729.
- European Commission (2014). “*Healthcare in your pocket: unlocking the potential of mHealth*” <http://europa.eu/rapid/press-release_IP-14-394_en.htm> [Accessed April 15, 2014].
- Dubois, C.A. and D. Singh (2009). From staff-mix to skill-mix and beyond: towards a systemic approach to health workforce management. *Hum Resour Health* **7**: 87.
- Giddens, A. (1984). *The constitution of society: Outline of the theory of structuration*. Cambridge: Polity Press.
- Harvard Magazine, 2014. *Why “Big Data” Is a Big Deal: Information science promises to change the world*, <http://harvardmagazine.com/2014/03/why-big-data-is-a-big-deal>> [Accessed April 15, 2014].
- Institutes of Medicine (2012). Best Care at Lower Cost: The Path to Continuously Learning Health Care in America, <<http://www.iom.edu/Reports/2012/Best-Care-at-Lower-Cost-The-Path-to-Continuously-Learning-Health-Care-in-America.aspx>> [Accessed April 15, 2014].
- Marmot M. (2013). *Health inequalities in the EU*, Brussels, <http://ec.europa.eu/health/social_determinants/docs/healthinequalitiesineu_2013_en.pdf> [Accessed April 15, 2014].
- McKinsey (2013). “*The big-data revolution in US health care: Accelerating value and innovation*” <http://www.mckinsey.com/insights/health_systems_and_services/the_big-data_revolution_in_us_health_care> [Accessed April 15, 2014]
- Roberts M., W. Hsiao, P. Berman, and M. Reich. (2003). *Getting Health Reform Right: A Guide to Improving Performance and Equity*. Oxford University Press: Oxford, UK.
- West, D. (2011). “*Enabling Personalized Medicine through Health Information Technology: Advancing the Integration of Information*”, Brookings Institution Report, January 2011.

7.8 Working group report: Environment and health challenge

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What is the challenge?

Overview

Addressing rapid global environmental change is the major health and wellbeing issue of the 21st Century. All other pressures and factors, from demographic change and widening inequalities to increasing urbanization and the international economic crisis, will worsen substantially in the face of this rapid environmental change. The focus of this challenge area is on the interactions between humans and the environment, and how these interactions create both risks and benefits/opportunities for the health of the environment and for human health and wellbeing. **The challenge facing us is to foster changes in human behaviour that are not only beneficial and rewarding, but which help us to live sustainably as the global environmental continues to change rapidly, now and in the future.** To this end, we need strategic planning coupled with motivation and public engagement.

In the challenge area of environment and health, “environment” has been defined in both small and large terms, encompassing the individual human biome to the built and natural environments to local and global environmental change, including but not limited to climate change. The following are key research actions needed in environment and human health:

- Explore and measure the beneficial and negative impacts, as well as the underlying mechanisms and behaviours, from the *interactions between the environment and human health and wellbeing*, taking an inter- and multidisciplinary/institutional/sector approach with stakeholder engagement and attention to social equity.
- Expand the use of *“big data” to include all types of data*, with innovative data “mashups” of health and environmental data linkages (including longitudinal data from existing and new databases), for the purposes of: surveillance, screening, and identification of high risk populations and inequalities; the study of “mechanisms”; the modelling of different approaches and scenarios; the creation of new methods; innovation; translation to policy makers and other stakeholders; etc.
- Promote *innovation with technology* to proactively *change behaviour towards more sustainable life styles* which promote both health and wellbeing and healthy ecosystems in a world of rapid environmental change; in this area, there is much to learn from developing countries.
- Provide concrete “motivational” examples at different levels (individual, familial, community, regional, national, international, and global) of *successful behaviour change around prevention, adaptation, mitigation and resiliency in the face of continual environmental change* demonstrating impacts both on health and wellbeing and on ecosystems.
- Move towards *sustainable health/public health/social care systems* which would serve not only as an important exemplar of best practice, but also as sources of innovation.

It is imperative that research into the environment and its effect on health, wellbeing and sustainable living does not fall between “between the stools” of the different Advisory Groups. It could be made an exemplar of horizontal truly interdisciplinary research traversing thematic priorities and uniting European researchers to the benefit of all our citizens. Of note, the Societal Challenge 5 Advisory Group, “Climate Action, Environment, Resource Efficiency and Raw Materials,” Final 2014 Report identified Environment and Human Health as **important cross cutting theme** at risk of “falling through the cracks,” but also **an important research and innovation theme which crosses multiple Advisory Groups**.

Local environments are changing rapidly across the entire planet, often with unexplored and unimagined short- and long-term consequences for human health and wellbeing. As well as climate change and associated extreme weather events, other forms of environmental change (such as biodiversity loss, pollution and ecosystem degradation) are increasing the pressures on the resources that sustain life (e.g. water, air, soil, and other ecosystem services). Increasing alienation from natural environments and their potential health and wellbeing benefits, as well as increasing inhaled, ingested and pervasive exposure over the life course to a vast mixture of chemicals and other anthropogenic stressors, are contributing to decreasing wellbeing and rising burdens of chronic diseases in a rapidly ageing human population. ***The challenge facing us is to identify both dangerous and beneficial exposures, and develop interventions to foster changes in human behaviour that are not only healthy and rewarding, but which help us to live sustainably as the global environment continues to change rapidly, now and in the future*** [UNEP Year Book, 2013].

Why is this a challenge?

Past attempts to improve human health and wellbeing have fallen within the domain of medical doctors and researchers. However, there is a growing awareness of the intimate relationship between a person’s health and wellbeing, and the environments in which they live their lives. Identification and measurement of the environmental determinants of health and wellbeing, and the mediating underlying mechanisms, are now urgently required in order to provide the evidential basis for effective health protection strategies and programmes, and to inform the EU policymakers.

The key challenges posed are to recognize that the environment poses threats to the health and wellbeing of the peoples of Europe, but also represents a largely untapped resource to enhance wellbeing and build resilience against physical and mental diseases. A related challenge is to find better ways to bring together experts from the diverse areas of natural and social sciences (as well as policy makers, industry and other stakeholders) to address the complex research questions in this area, thereby overcoming entrenched narrow approaches to the problems facing us. Research into the causes and impacts of environmental change is growing, supplying knowledge from restricted disciplinary areas on specific targets. There is an urgent need to nurture cross pollination of research between disparate aspects of global ecological, health care and social systems, with policy impact.

Action/research needed

A truly interdisciplinary and inter-institutional approach is urgently needed that involves not just natural, social and biomedical scientists, but also businesses, policy makers, and communities. Targeted approaches to tackling questions must be supplemented by wider thinking to ensure direct policy and regulatory relevance. As well as the potential risks, the current and future health and wellbeing benefits and opportunities associated with policy measures being taken to mitigate and adapt to environmental change must be made transparent and fully realized. ***A new more holistic approach to and an appreciation of the complex health and the environment paradigm are needed, as well as the inclusion of health/wellbeing and the environment aspects in all policies.*** Successful examples of the applications of best practice at the individual, community, ecosystem, and societal levels are needed to inspire all stakeholders, as well as applied research on solutions and risk management approaches for uncertain risks [UNEP, 2006].

The priority areas of expertise from both natural and social sciences (as well as other stakeholders) that need to be drawn together to tackle the complex "wicked problems" of rapid environmental change include: those working on climate change science, ecosystem services and biodiversity loss, environmental toxicology, medicine and public health, behaviour change, engineering, renewable energy and transportation, and food and water security. Furthermore, rapid demographic changes and inequitable distribution of existing resources, as well as disparate impacts of rapid environmental change in different areas of the world, are additional important priorities.

To date, a great deal of research has focused on the risks (e.g. the implications of water scarcity on drinking water quality, the effects of air pollution, or increased exposure to UV radiation through depleted ozone). ***Given the uncertainties of risk predictions, a shift of emphasis to the exploration of potential opportunities and benefits of truly engaging with rapid environmental change may be a valuable way forward.*** For example, will increasing the use of renewable energy and sustainable transportation, as well as increased interactions with natural environments, lead to increased wellbeing? A focus on determining what kind of environment we are aiming to achieve in addition to a more conventional strategy put in place to deal with the emerging consequences of our poorly conceived prior actions may be the way forward. Our ability to translate existing knowledge of environmental and social interconnections into specific actions and interventions is poorly developed. Finally, the complicated causal chains and webs of interactions, both in terms of short- and long-term impacts on both humans and ecosystems, have not been taken into account [WHO, 2000].

Innovation needed in relation to the challenge

Action

A better understanding of the environmental and socio-environmental determinants of health during the life course from conception, pregnancy and childhood through to the elderly will require integrated molecular biological, exposure assessment, epidemiological, toxicological, and systems approaches to investigate these complex health–environment relationships. This needs to be seen in light of rapidly changing demographics (e.g. longer living populations, often with chronic diseases) as well as socio-economic–political inequalities. Environmental health studies should examine the impacts and mechanisms of chemical exposures, combined exposures to pollution (mixtures), and other environmental and climate-related stressors (e.g. air pollution, water and soil contamination, noise, temperature, light pollution, radiation, pharmaceuticals [including drugs of abuse and

antibiotic resistance], food contamination and man-made nanoparticles) and benefits (e.g. green and blue spaces, alternative transport and urban planning), as well as alternatives to animal testing. We need innovative approaches to exposure assessment using new-generation biomarkers based on “omics” and epigenetics, human biomonitoring, personal exposure assessments, and modelling which integrate socio-economic and behavioural factors to understand combined, cumulative, and emerging exposures and their health effects. Improved links between health and environmental data using advanced information systems should be supported to provide this information [Fleming, 2013; Wild, 2005].

But this will not be enough. ***Innovations in the social sciences will ultimately provide the answers*** to questions such as: why do we persist in adopting lifestyles that expose humans to anthropogenic health threats? This will involve behavioural studies at all levels (individual, community, ecosystem, national), as well as the development of innovative strategies and tools to communicate and foster better directions of travel towards more sustainable behaviours and lifestyles throughout the life course [Behavioural Insights Team UK Government, 2011].

Research into the area of health and wellbeing from interactions with the natural environment should not only address chronic health issues (e.g. mental illness, obesity and related diseases, cancer, etc.), but also instil ***a greater appreciation of the importance and value of sustainable ecosystems to the current and future health and wellbeing of human populations***. Benefits of spending time outdoors in natural environments have already been demonstrated in terms of exercise and other activities in green and blue spaces. More research is required to determine the underlying biological (environmental epigenetics) and psychological mechanisms by which benefits arise. Comparisons of rural and urban environmental effects, particularly on deprived populations, need to be examined rigorously to assemble an evidence base to guide future policies for health and wellbeing equality [Natural England, 2012; Wheeler, 2012; White, 2013].

Case studies of successes and lessons learned at all scales are required of the short and long term health and wellbeing implications for both humans and ecosystems of, for example, the uses of renewable energy and associated technologies, as well as other sustainable technologies, particularly within the health and public health sectors. And there is a lot to learn in the area of innovative sustainable approaches from the developing nations. For example, findings from a recent survey of access to electricity in health care facilities in selected countries in sub-Saharan Africa revealed that less than a third of health care facilities had access to reliable electricity; the increasing use of low-carbon energy technologies (e.g. solar) to address this energy gap is not only generating significant benefits in terms of lives saved, it also supports wider climate objectives [Adair-Rohani *et al.*, 2013].

Making the health care and public health systems and services truly sustainable with regard to climate and other environmental changes would serve as both exploration and demonstration of best practice to inspire innovation and stakeholders across society and internationally. Opportunities presented by the existing and emerging “e”/ICT technologies should be explored to provide benefits, as well obviate risks, to the health of both humans and ecosystems [NHS 2014 Sustainable Health Strategy].

Through the linkage of existing cohort studies, registries and aligned resources (as seen with current “exposome” research), ***the exploitation of existing and the development of new representative populations will provide a means of surveillance to explore and evaluate the health and wellbeing impacts of environmental exposures over the life course***. “Data Mashups” of climate, environmental, and human health and wellbeing databases can identify populations which are vulnerable in terms of risk of impacts from environmental change and

from socio-economic/historic deprivation; interventions can be targeted for implementation and evaluation in these highly vulnerable communities. Specific targeted short- and long-term exposure studies will provide information on new environmental hazards or interactions of various environmental, social, economic, and other contextual as well as personal factors with human health, thereby supplying the evidence base for specific preventive actions. Targeted studies utilizing ICT and other new technologies will be necessary to evaluate the impact of interventions (preventive as well as therapeutic) [Fleming, 2013; Wild, 2005].

Products

New applications of existing ICT and development of New ICT to: monitor environmental and occupational exposures; deliver health and wellbeing for humans and ecosystems using portable or wearable technology; encourage behaviour change towards more sustainable behaviours at the individual, community, and societal levels; make available and communicate sustainable living to diverse and previously disenfranchised individuals and communities; quantify risk and benefits in monetary and other terms; prevent hazardous exposures; prevent and mitigate the ecosystem impacts of sustainable living. Large data mashups with both natural science and social science data will provide new directions for innovation and research by identifying vulnerable areas, allowing modelling and prediction, creating new approaches and methodologies, and providing populations and areas for evaluation of new responses to rapid environmental change.

The impact that the use of medical and wellbeing devices has on the environment is also important because of related requirements for power and energy, and the opportunity provided by global interest in mitigation of environmental change to power these devices using cleaner more sustainable energy technologies and sources. Innovation can take place in the development of products which can reduce environmental impacts (e.g. green chemistry, health care technologies with smaller environmental footprints), and help protect health and wellbeing from the adverse effects of environmental or ecosystem changes (e.g. integrated surveillance of environmental conditions, health risks, outcomes). To encourage and achieve sustainability, incorporation of true “cradle to grave” costs into all human activities and products will be necessary [Fujitsu Sustainability and the Environment, 2011; UNEP 2014 Green Business].

Success criteria

Research, innovation, economy, health care, public health, environment/ecosystems

In this Challenge area (although arguably in all Challenge areas), it is especially important to consider both the beneficial and risky impacts of the environment and ecosystems on human health. Success will be measured in the establishment and success of truly interdisciplinary and innovative research and research communities involving potential stakeholders into both the potential risks and benefits of the current and future interactions between the environment and human health and wellbeing. Another measure will be the integration of the environment as integral to health and wellbeing into all health policies; and health and wellbeing into all environmental policies. Measurable change should be demonstrated in the public and policy maker opinion and understanding of both the importance of environmental change on human health and wellbeing, and the influence that humans and their behaviour have on the health of the environment/ecosystems. Finally, an engaged society, cognisant of its responsibilities and active in promoting healthier lifestyles and a greener environment, will be the ultimate metric of success.

Internationalization and collaboration

Rapid environmental change is a local, national, regional, and global phenomenon. As such it cannot be addressed without approaches at all these levels, as well as at the individual, community, ecosystem, and societal levels. And as discussed above, nor can this be addressed without truly interdisciplinary and inter-institutional collaborations bringing together the social science and natural science communities.

In addition, we have *much to learn from the developing nations about adaptation and mitigation of environmental change and living more sustainably*. These countries have lived in resource-restricted environments with increasing pressures of rapid environmental change; they have examples of the applications of innovative uses of new and existing technologies in resource-poor environments which can be adapted for use in the developed nations of the EU [UK Parliament Postnote ICT in Developing Countries, 2006].

Description of the barriers

Bottlenecks: Where are they? How can they be alleviated?

Environmental change in relation to human health and wellbeing has largely not been addressed because of its very complexity and scale. There are upstream drivers (outside of direct control of the health sector), long and interacting causal chains, complex interactions, multiple stakeholders, and a tradition of end-of-pipe interventions, all of which act as barriers to effective policy and behaviour change at all levels. In addition, we have not developed appropriate approaches to risk management under the scale of uncertainty (e.g. precautionary principle) associated with rapid environmental change.

Research on environmental change and health has been “siloeed” with little collaboration and interaction between natural, social and biomedical researchers, and has suffered from a history of decreasing acceptance of its potential impact and interconnectedness by the general population and some policy makers, particularly around climate change. The truly interdisciplinary research needed in this area will be inherently risky and innovative; current peer review and funding mechanisms do not tend to reward this type of research. Evaluation of the health effects of multiple community exposures has been limited by existing methods and technologies. Innovative approaches and technologies both in environmental exposure assessment and in mechanistic studies that have only recently become available have not been yet widely applied. Furthermore, it has been difficult to translate research findings into innovations and policies, particularly around the possible co-benefits and opportunities. The magnitude and complexity of the interconnected issues around the health and wellbeing of humans and ecosystems are apparently incomprehensible and potentially demoralizing to policy makers and the general public.

Risks: What are they? How can they be minimized or avoided?

If we as individuals, communities, and societies do not address the causes and impacts of current environmental exposures and of rapid environmental change on the short- and long-term health and wellbeing of humans, we will increasingly experience these deleterious impacts. Furthermore, these impacts will be felt inequitably by deprived and environmentally at risk communities around the world.

Therefore, broader interdisciplinary and inter-institutional collaborations with involvement of stakeholders are essential in addition to targeted approaches to identify and evaluate specific

challenges. ***Demonstrable sustainable approaches with innovation opportunities and potential co-benefits at the individual, community, ecosystem, and societal levels are needed, as well as improved and targeted bidirectional communication and dissemination of these approaches and of the scientific concepts.***

Key risks include:

- There is a major shift in the global policy debate related to environmental change, for instance precipitated by another global financial crisis which results in less interest and priority being given to research activities and actions in environment and health. Similar risks apply at the national and local levels.
- Gaps in institutional capacities in conducting research on environment and health at the scale of some of the greatest environment and health challenges, which in turn becomes a major barrier requiring more than foreseen investment in capacity development.
- The health-/social care/public health sector fails to fully embrace the environment and health sustainability agenda, and therefore does not see these "nexus" issues to be within their purview of responsibility. Ensuring clear and early ownership of the health sector of this process will be critical to the success of the intersectoral action needed to move this agenda.

Gaps: where are they and how can they be closed?

There are gaps in the research with regard to particularly the opportunities and co-benefits of preventing, mitigating and adapting to current environmental exposures and rapid environmental change. Again interdisciplinary and inter-institutional collaboration with involvement of all stakeholders at all levels is needed as well as integration of policy makers.

Game changers

What are the game changers that would significantly help to meet this challenge and how can they be developed and implemented?

Possible positive game changers include the identification of truly sustainable, affordable and scalable energy sources without future impacts on the health of both humans and ecosystems. In addition, concrete evidence and successful implementation of adaptive or interventional approaches to deal with current environmental impacts represent positive game changers.

Role of the public sector

What is the public sector's role and how should it best be implemented?

The public sector, particularly but not exclusively health care/social care/public health, could be the leader in identifying and demonstrating sustainable approaches which increase human health and wellbeing. The public sector is key to providing vision, innovation, setting regulation, and pump-priming technologies. The public sector can also establish guidelines for sustainable innovation with and for industry and SMEs before moving to specific functions, processes and products.

Strong areas for industry and SMEs [UNEP 2014 Our Planet Greening Business]

Bottom-up activities

- Development and applications of e/ICT in the monitoring of environmental exposures and delivery of health and wellbeing in a rapidly changing environment.
- Development of communication and stakeholder engagement tools.
- Development of local approaches to prevent, mitigate and adapt to environmental change.

Industrial roadmap

- Planning for and dealing with sustainable lifestyle, occupation, energy, waste and impacts of rapid global climate change on health at local, national, and international level within rapidly changing human populations and environmental/ecosystem change.
- Incorporation of the true costs of “cradle to grave” impacts into all manmade products and projects.
- Expansion and application of renewable energy, active transportation, city renewal and effects on human health. Expansion and application of renewable energy as well as technology improvements to medical devices to facilitate their use with low-carbon energy technologies (e.g. solar panels), and their impacts on human health/wellbeing and on ecosystems.
- Development of regional, national and international approaches to prevent, mitigate and adapt to environmental change to improve human health with assessment of co-benefits.

Strong areas to support integrated activities for each of the big challenges

Addressing rapid global environmental change is the major health and wellbeing issue of the 21st Century. All other pressures and factors, from demographic change and widening inequalities to increasing urbanization and the international economic crisis, will worsen substantially in the face of this rapid environmental change. To address the risks and possible co-benefits will take truly interdisciplinary and inter-institutional collaborative approaches to living sustainability now and into the future to minimize ecosystem harm and maximize human health and wellbeing. The longer we take to begin this process, the more reactive and less innovative will be our responses.

- Going beyond the “Health in all Policies” approach and paradigm to “***Health and Environment in all Policies***” as a recognition of the absolute importance of the interconnections between environment and human health/wellbeing and the need for sustainability [WHO 2014, Health in All Policies].
- ***A joined up interdisciplinary community of researchers*** bringing together social sciences and natural sciences with stakeholder engagement and bidirectional communication.
- ***Innovations in the social sciences to provide the answers*** to questions such as: why do we persist in adopting lifestyles that expose humans to anthropogenic health threats? And integration with more quantitative, ecosystem services, and biomedical approaches (e.g. new metadiscipline of Oceans and Human Health) [Fleming, 2014].
- ***A better understanding of the environmental and socio-environmental determinants of health during the life course*** from pregnancy and childhood through to the elderly,

including influences such as deprivation, will require integrated molecular biological, exposure assessment, epidemiological, and toxicological approaches to investigate health–environment relationships.

- Research into the area of health and wellbeing from interactions with the natural environment should not only address chronic health issues (e.g. mental illness, obesity and related diseases, cancer, etc.), but also instil ***a greater appreciation of the importance and value of sustainable ecosystems to the current and future health and wellbeing of human populations.***
- ***Making the health care and public health systems and services truly sustainable*** with regard to climate and other environmental changes would serve as both exploration and demonstration of best practice to inspire innovation and stakeholders across society and internationally.
- Through the linkage of existing cohort studies, registries and aligned resources (as seen with current “exposome” research), ***the development of representative populations will provide a means of surveillance to explore and evaluate the health and wellbeing impacts of environmental exposures over the life course.***

SWOT analysis

<p>Strengths</p> <p>Increasing evidence of both benefits and opportunities from addressing rapid environmental change.</p> <p>Examples of interdisciplinary research and approaches.</p> <p>Excellence and leadership in environmental health research worldwide.</p> <p>Strong collaborative research.</p> <p>Large ongoing studies funded by the EU (e.g. Exposome).</p> <p>Extensive interactions between research groups.</p> <p>Multidisciplinary research approach.</p> <p>New biotechnologies and technologies on exposure assessment.</p>	<p>Weaknesses</p> <p>Focus on the short term.</p> <p>Hopelessness and denial of issues.</p> <p>Silos of research, policy.</p> <p>Lack of global view in existing studies.</p> <p>Difficulties in evaluating complex scenarios.</p> <p>Lack of communication between related specialties.</p>
<p>Opportunities</p> <p>Exploitation of green technologies and renewable energy and research into co-benefits of adaptation, mitigation strategies.</p> <p>Emphasis on benefits of interactions with natural environment.</p> <p>Local efforts and case studies (including in developing world) can be exportable and scalable.</p> <p>Increasing joining up of large longitudinal diverse human health studies (e.g. exposome, UK biobank).</p> <p>European and International research agendas, including Global Health.</p> <p>High social awareness of the environment and health.</p> <p>High critical mass of biomedical research on environmental health in the EU.</p> <p>Developments in new biomedical and exposure assessment techniques, including –omics.</p> <p>Provision of evidence for public health policies.</p> <p>Public-private partnership for development of innovative technologies and interventions.</p>	<p>Threats</p> <p>Rapid advance of environmental change.</p> <p>Global economic deterioration.</p> <p>All leading to increased local, regional and global conflict Interest most on environment rather than effects of environment on health.</p> <p>Health research focused on biotechnology rather than wider societal/environmental issues.</p> <p>Lack of long-term funding frameworks.</p> <p>Insufficient political (national and international) support for environmental health research.</p>

Key References

Adair-Rohani H, Zakora K, Bonjoura S, Wilburna S, Kuesela AC, Hubert R & Fletcher ER. (2013). Limited electricity access in health facilities of sub-Saharan Africa: a systematic review of data on electricity access, sources, and reliability *Glob Health Sci Pract* **1**(2): 249–261.

Fujitsu. Sustainability and the Environment Report 2011. <https://www.fujitsu.com/global/Images/fujitsu2011report-e.pdf>

Fleming LE, Haines A, Golding B, Kessel A, Cichowska A, Sabel CE, Depledge MH, Sarran C, Osborne N, Whitmore C & Bloomfield D. (2014). Data Mashups: Potential Contribution to Decision Support on Climate Change and Health. *International Journal of Environmental Research and Public Health* **11**: 1725–1746.

Fleming LE, McDonough N, Austen M, Mee L, Moore M, Depledge MH, White M, Philippart K, Bradbrook P & Smalley A (2014). Oceans and Human Health: A Rising Tide of Challenges and Opportunities for Europe. *Marine Environment Research* **99**: 16–19.

Natural England. Health and Natural Environments: An evidence based information pack, March 2012 http://www.naturalengland.org.uk/Images/health-information-pack_tcm6-31487.pdf

UK Government Behavioural Insights Team. Behaviour Change and Energy Use. 2011 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/60536/behaviour-change-and-energy-use.pdf

UK National Health Service (NHS). Sustainable, Resilient, Healthy People & Places: A Sustainable Development Strategy for the NHS, Public Health and Social Care system. 2014 http://www.sduhealth.org.uk/documents/publications/2014%20strategy%20and%20modulesNewFolder/Strategy_FINAL_Jan2014.pdf

UK Parliament Postnote. ICT in Developing Countries. Postnote 261, 2006 <http://www.parliament.uk/documents/post/postpn261.pdf>

United Nations Environment Programme (UNEP). Year Book 2013: Emerging Issues in Our Global Environment, 2013 http://www.unep.org/pdf/uyb_2013_new.pdf

United Nations Environment Programme (UNEP). Preventing Disease Through Healthy Environments: Towards an Estimate of the Environmental Burden of Disease, 2006 http://whqlibdoc.who.int/publications/2006/9241593822_eng.pdf

United Nations Environment Programme (UNEP). Our Planet Greening Business, April 2014 <http://biodiversity-l.iisd.org/news/uneps-our-planet-magazine-releases-special-issue-on-greening-business/>

Wheeler BW, White M, Stahl-Timmins W & Depledge MH (2012). Does living by the coast improve health and wellbeing? *Health Place* **18**(5): 1198–1201.

White MP, Alcock I, Wheeler BW & Depledge MH (2013). Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. *Psychol Sci* **24**(6): 920–928.

Wild CP (2005). Complementing the genome with an “exposome”: the outstanding challenge of environmental exposure measurement in molecular epidemiology. *Cancer Epidemiol. Biomarkers Prev.* **14**: 1847–1850.

World Health Organisation (WHO). Transport, Environment and Health. Document 89, 2000

http://www.euro.who.int/_data/assets/pdf_file/0003/87573/E72015.pdf

World Health Organisation (WHO). Health in All Policies, 2014 http://www.who.int/cardiovascular_diseases/140120HPRHiAPFramework.pdf?ua=1

7.9 Swot analysis – summary

Challenge	Strengths	Weaknesses	Opportunities	Threats
<p>1) Ageing at large</p>	<p>Widespread government interest to adapt to demographic change.</p> <p>Societal expectations that ageing should be healthy.</p> <p>Research and development of new models, products and applications are often sought and welcomed.</p> <p>Some knowledge exists, especially in countries already affected by the demographic revolution (e.g. Japan).</p>	<p>Current knowledge limited in scope and depth, little implementation science, ageist stereotypes lead research to outdated solutions.</p> <p>Poor understanding of fundamental ageing process and drivers of frailty and dependency.</p> <p>Inadequate research in older, frailer cohorts.</p> <p>Lots of pilots but not enough investment in scaling up and evaluation. Absence of coordinated and coherent application of research outcomes.</p> <p>Cross-sectoral collaboration as a routine is still not the norm.</p> <p>Lack of comparable harmonized information across countries to better understand risk factors and best practice and policy.</p> <p>Inadequate collection of large longitudinal datasets for cross-country comparison of objective</p>	<p>New appreciation of the importance of ageing in health and development for countries of all levels of development.</p> <p>Industry/SMEs/academia collaboration, in and beyond the health sector to develop older-people-friendly and older-people-centred health technologies – including assistive devices – and ICT applications.</p> <p>Well-developed models of cross disciplinary longitudinal data collection which can be replicated across cultures.</p> <p>Significant opportunities to develop better service delivery and integration models for countries at all levels of development</p>	<p>Ageing perceived only as a cost to society.</p> <p>Solutions led by technology rather than by patient-centred needs.</p> <p>New proposed EU legislation restricting scientific exploration of extant data sets.</p>

		and subjective measure of health and other relevant information.		
2) Personalized medicine, mechanisms, system medicine, biomarkers, diagnostics	<p>Comparatively strong health care system infrastructures to conduct clinical studies.</p> <p>Longitudinal/prospective cohort studies.</p> <p>Strong basic research.</p> <p>Rapid advances in ‘omics’ including decreasing costs.</p>	<p>Insufficient interdisciplinarity, existence of ‘silos’.</p> <p>Different health care systems and regulations across EU.</p> <p>Insufficient entrepreneurship, making implementation of personalized medicine in real life challenging.</p> <p>Lack of joined up databases.</p> <p>Lack of training of health care and other providers.</p>	<p>Need for new business models.</p> <p>Need for improved public health.</p> <p>Need for change to health care systems to reduce costs.</p>	<p>Inadequately addressing the risks associated with personalized medicine, such as issues of data privacy/ownership and security.</p> <p>Resistance to change. Despite demonstrated success, public and health care professionals do not support implementation of personalized medicine.</p>
3) ICT for health	<p>New technologies and increased access to broadband even in low-income settings.</p> <p>Health care expectations from ICT are high, so new products and applications are often sought and welcomed.</p> <p>Large knowledge base exists.</p>	<p>Not enough evidence on benefits and not enough investment in evaluation and training.</p> <p>Absence of coordinated and coherent application of research outcomes.</p> <p>Cross-sectoral collaboration as a routine still not the norm.</p> <p>User-centred design also still not the norm. Older, frailer cohorts often left out of consultation.</p>	<p>Industry/SMEs/academia collaboration, in and beyond the health sector.</p> <p>New appreciation of the importance of ICT in health and development.</p>	<p>IP issues and commercial drive of vendors.</p> <p>Competitive rather than collaborative research.</p> <p>Older people seen as not able, or afraid, to take up technology.</p>
4) Population health and health promotion	<p>Longitudinal population-based cohort studies with research biobanks.</p>	<p>Insufficient insight into causal mechanisms of different conditions to be targeted.</p>	<p>Need to start early in kindergarten and schools to prevent mental illnesses.</p>	<p>Resistance to change behaviour.</p>

	Strong tradition with many intervention programmes for different conditions.	Demanding and time consuming clinical work offers less time to do interventions.	Need for improved mental health and reduced lost years of work in all countries. Need for using new technology when conducting research and implementing programmes. Need for change from costly treatment to cost-effective prevention.	
5) Infectious diseases at large	New technologies – reverse vaccinology, gene manipulation, synthetic biology, bioinformatics, genomics, proteomics, all the ‘omics’. Health care expectations are high, so new products and interventions are often sought and welcomed. Large knowledge base exists.	Little progress in recent years despite investment. Industry reticence due to high risk, low return. Much of large knowledge base not fully accessible. Outdated and maladapted approaches to R&D slow down the research pipeline and impede the coordinated and coherent application of research outcomes. Cross-sectoral collaboration as a routine still not the norm.	Emerging threats with potential very high morbidity, industry academia collaboration, long term effects of chronic and occult infections, growing acceptance of ‘One Health’ concepts and impacts. New appreciation of connections between infection and chronic disease states and cancer.	IP issues and patent “thickets”, uncontrolled use of new drugs, public resistance to vaccines, breakdown of health systems following financial downturn. Failure to build capacity and trust across stakeholder groups has led to distrust and resistance to “follow orders”. Concerted public engagement with outreach/educational campaigns to explain information and empower individuals based on informed decision making, as opposed to the current very hierarchical model which fails to empower the individual. Persistence of a ‘publish or perish’ research culture despite reductions in research

				<p>spending encourages competitive rather than collaborative research.</p> <p>Opportunities to look at how information is disseminated and its impact.</p>
6) Early development	<p>At-risk children cannot wait.</p> <p>Longitudinal prospective cohort studies.</p> <p>Resilience research conveys hope and not only adversity.</p> <p>Investing in early interventions reduces adult disease and disorders and returns more money than it costs.</p>	<p>Difficult to develop efficient content of intervention programmes.</p> <p>Successful programmes tend to be costly due to a lack of an interdisciplinary, collaborative approach rather than a given.</p> <p>Longitudinal studies tend to be too short.</p>	<p>Need for integrating medical and psychological research.</p> <p>Need for a greater recognition for understanding early development.</p> <p>Need for changing investment in post-school age to pre-school age.</p> <p>Need for implementing new causal research findings into programmes.</p>	<p>Inadequate account taken of social context and cultural differences when generalizing findings.</p> <p>Research ethics in early development studies can pose restrictions on cutting-edge research.</p> <p>Interventions can have both, positive and negative effects.</p>
7) Sustainable health and care systems	<p>Real-time data and big data management have the potential to yield improved patient monitoring and quality of care.</p> <p>Health Management Information Systems allow managers and policy makers to monitor processes and outcomes, enabling greater efficiency and effectiveness of health systems.</p> <p>Patients, families and</p>	<p>Underdeveloped systems to manage large volumes of data, including their analysis, interpretation and integration into practice and policy.</p> <p>Lack of standardized methodology to measure and assess performance, quality of care and patient satisfaction.</p> <p>Lack of integration between health and social care.</p> <p>Need for greater political commitment and leadership</p>	<p>Participatory medicine: learning and responsive health systems can foster patient engagement, leading to increased public satisfaction.</p> <p>New approaches to integrated care and population management are emerging.</p> <p>Business: innovative services and start-ups/spin-offs on real time data management.</p> <p>International collaboration and cross-learning opportunities in</p>	<p>Competing and often contradictory interests (e.g. pharmaceutical lobby for enhanced IP rights protection vs. civil society advocacy towards access to generic medicines).</p> <p>Information and data produced are often not understandable for all stakeholders to make informed decisions.</p> <p>Threats to individual confidentiality, privacy and</p>

	<p>communities have access to information allowing them to serve as engaged co-producers of their own care.</p>	<p>towards learning and responsive health systems.</p> <p>Weak population and environmental focus.</p>	<p>using big data to inform policy and practice.</p> <p>Collaborations across stakeholder groups including: the general public, policy makers, government agencies, NGOs, research institutes, SMEs, students of all ages, alumni, the corporate sector, practitioners, funders and philanthropies.</p>	<p>security of patient information.</p> <p>Misuse of data by vested commercial interests, e.g. for promoting unnecessary medical procedures or superfluous drugs.</p> <p>Lack of human resources in terms of mix and numbers.</p>
8) Environment and health	<p>Increasing evidence of both benefits and opportunities from addressing rapid environmental change.</p> <p>Examples of interdisciplinary research and approaches.</p> <p>Excellence and leadership in environmental health research worldwide.</p> <p>Strong collaborative research.</p> <p>Large ongoing studies funded by the EU (e.g. Exposome).</p> <p>Extensive interaction between research groups.</p> <p>Multidisciplinary research approach.</p>	<p>Focus on the short term.</p> <p>Hopelessness and denial of issues.</p> <p>Silos of research, policy.</p> <p>Lack of global view in existing studies.</p> <p>Difficulties in evaluating complex scenarios.</p> <p>Lack of communication between related specialties.</p>	<p>Exploitation of green technologies and renewable energy and research into co-benefits of adaptation, mitigation strategies.</p> <p>Emphasis on benefits of interactions with natural environment.</p> <p>Local efforts and case studies (including in developing world) can be exportable and scalable.</p> <p>Increasing joining up of large longitudinal diverse human health studies (e.g. exposome, UK biobank).</p> <p>European and International research agendas, including Global Health.</p> <p>High social awareness of the</p>	<p>Rapid advance of environmental change.</p> <p>Global economic deterioration.</p> <p>All leading to increased local, regional and global conflict.</p> <p>Interest most on environment rather than effects of environment on health.</p> <p>Health research focused on biotechnology rather than wider societal/environmental issues.</p> <p>Lack of long-term funding frameworks.</p> <p>Insufficient political (national and international) support for environmental health research.</p>

	<p>New biotechnologies and technologies on exposure assessment.</p>		<p>environment and health.</p> <p>High critical mass of biomedical research on environmental health in the EU.</p> <p>Developments in new biomedical and exposure assessment techniques, including 'omics'.</p> <p>Provision of evidence for public health policies.</p> <p>Public-private partnership for development of innovative technologies and interventions.</p>	
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8. Annexes

8.1 Template for AG report 2014

For each Challenge (1, 2, 3, 4, 5, 6, 7, 8; see list below) the following questions were reflected in the reports of the SC1 AG working groups:

What is the challenge?

Why is this a challenge?

Action/research needed to meet the challenge

Innovation needed in relation to the challenge

- o **Action:** Health care, public health, EU, others
- o **Product:** Drug, ICT, medical devices, others

Success criteria:

- o Research
- o Innovation
- o Economy
- o Health care
- o Public health

Internationalization and collaboration

Bottlenecks:

Where are they and how can they be alleviated?

Risks:

What are they? How can they be minimized or avoided?

Gaps:

Where are they? How can they be closed?

Game changers:

What are they and how can they be developed and implemented?

Role of the public sector:

What is it and how can it be implemented?

Strong areas for industry and SMEs:

Bottom-up activities: Mention most relevant.

Industrial roadmap: Mention most relevant.

Strong areas to support integrated activities for each of the big challenges

The overarching theme will be public health and health care changes, important aspects for rising costs and declining economy, and urbanization and change demography. For each challenge these overarching areas and cross-cutting activities should also be dealt with:

- Social science and humanities
- Responsible research and innovation, including gender aspects
- Climate and sustainable development
- Interdisciplinary activities

8.2 Consultation of the Horizon 2020 Advisory Groups

Providing advice on potential priorities for Research and Innovation in the Work Programme 2016–2017.

Introduction

Horizon 2020 Advisory Groups are consultative entities set up by the Commission to provide strategic advice for the preparation of the work programmes, regarding the relevant challenge/part of the Specific Programme implementing Horizon 2020.

Representing the broad constituency of stakeholders including both industry and research actors as well as representatives of civil society, Advisory Groups are a valuable source in terms of providing advice based on their expertise on the research and innovation investments needed, on cross-cutting aspects, as well as considering the state of research and innovation agendas in relation to potential priority areas.

This paper provides the basis for the consultation of the Horizon 2020 Advisory Groups towards providing input on potential priorities for EU research and innovation funding in the work programme 2016–2017.

The Horizon 2020 Specific Programme sets the scope and content for the implementation of the Framework Programme for research and innovation (2014–2020). Providing the legal base as politically agreed with the Member States and the European Parliament, it determines the specific objectives for Union support to the research and innovation activities for each Horizon 2020 challenge/part. On this basis, the Commission services prepare multiannual work programmes of which the first Horizon 2020 work programme covering 2014–2015 was adopted on 10 December 2013.

This consultation is the first step in the process towards preparing the next work programme covering 2016–2017 and is organized around meetings of the groups taking place from mid-March until end-June 2014.

The preparation of the work programme 2016–2017 first includes a consultation with the stakeholder community, in particular through the Advisory Groups on the basis of a series of questions (provided in Part 4 of this document). Other main stakeholders such as European Technology Platforms, European Innovation Partnerships, Joint Programming Initiatives, contractual Public-Private Partnerships and other representatives from professional organizations and civil society will be consulted in parallel, where relevant. An exchange with the Member States will take place in the second part of the year. The Commission expects, on the basis of the priorities identified through these consultation processes, to then develop the

content of the work programme 2016–2017 in first half of 2015 with the adoption and publication of the calls for proposals not earlier than summer 2015.

The Horizon 2020 work programme comprises 18 sections, which set out the funding opportunities under the different parts of the programme. Each part is self-contained, and describes the overall objectives, the respective calls, and the topics within each call. The Horizon 2020 work programme is complemented by the separate work programmes for the European Research Council, Euratom, the Joint Research Centre, the strategic Innovation Agenda for the European Institute of Innovation and technology (EIT), as well as the Innovation Investment Package, still subject to inter-institutional negotiations, containing the Article 187 Joint Technology Initiatives with industry and Article 185 Public–Public Partnerships with Member States.

Key strategic considerations for strengthening the added value of EU actions

With its emphasis on addressing societal challenges and key technologies, covering the full research and innovation cycle, facilitating collaborative and industry-driven research, reducing time to market and further strengthening excellence, Horizon 2020 provides powerful opportunities to develop new knowledge and innovative products and services, creating growth and jobs in Europe.

The thematic content of the Specific Programme has to be translated into work programmes that deliver on these goals, making full use of the European added value that transnational collaboration can deliver. However, prioritization is needed as everything cannot be done at once, and the implementation of activities needs to be optimized.

This consultation is about helping to identify the potential areas and actions which could be rolled-out in the next work programme, taking into account such aspects as societal change, ageing population, big data, globalization, resource constraints, and environmental concerns; mobilizing resources to build scale and critical mass; exploiting well-developed research and innovation agendas; and securing world class scientific and innovative breakthroughs.

Concerning the first Horizon 2020 work programme 2014–2015, the overriding priorities are to boost competitiveness and support the creation of jobs and new sources of growth. A strong emphasis is placed on addressing societal challenges with high potential for sustainable competitiveness, innovation and growth. Thus reflecting the strong challenge-based approach of Horizon 2020, inviting applicants to come up with innovative solutions and attracting more multidisciplinary and multi-sectorial proposals.

Context of consultation

Delivering on the Europe 2020 objectives of smart, sustainable and inclusive growth depends on research and innovation as key facilitators of social and economic prosperity and of environmental sustainability. Linking EU research and innovation closer to policy objectives sets the framework and specific objectives to which Horizon 2020 research and innovation funding should contribute, such as the Europe 2020 Strategy, the Innovation Union and other flagship initiatives. In pursuit of the smart, sustainable and inclusive growth strategy, the recently adopted Commission communication provides a stock taking of the Europe 2020 strategy¹.

The general objective of Horizon 2020 will be pursued through three priorities dedicated to generating excellent science, creating industrial leadership, and tackling societal challenges. While the Specific Programme defines the specific objectives and rules for implementation for the duration of the framework programme, it does not define how these objectives are translated into specific actions, nor the sequence of roll-out of the actions. In particular taking into account, how to optimize the specific actions in view of the broader and horizontal objectives, i.e. its contribution to growth and jobs, the European added value and their framing in the context of research performed at Member States and international level.

Annex I to this paper contains the Specific Programme where the broad lines of the activities are defined.

Annex II is based on foresight evidence and provides an overview of the relevant drivers of future change and their potential disruptive effects, and an analysis of strategic considerations for Horizon 2020. It includes the identification of examples of possible areas of strategic importance and cross-cutting themes.

In addition, background information will be supplied that focuses on facts and trends relevant to the respective Horizon 2020 challenge/part of the Specific Programme, including the EU policy objectives and findings from assessments of previous EU funded research and innovation activities.

This paper, with its annexes, serves as a common basis for each advisory group to provide its advice on the potential strategic considerations (i.e., priorities) for the research and innovation activities in the work programme 2016–2017.

¹ COM(2014) 130 final

Questions

Building on the first Horizon 2020 work programme 2014–2015, this consultation will provide a more strategic approach to work programme preparations. This will enable a more integrated approach, particularly important for areas that cut across different Horizon 2020 parts and for linking key enabling technologies to their application in addressing societal challenges and vice versa.

On the basis of this paper and its accompanying annexes, the questions below are the key aspects to be considered in terms of providing input towards the priority setting for EU research and innovation funding in the work programme 2016–2017.

The questions to be considered by each Advisory Group, in what concerns their areas of expertise, are set out in the following box.

Please consider the following questions, citing any available evidence such as foresight and other assessments of research and innovation trends and market opportunities:

- What is the biggest challenge in the field concerned which requires immediate action under the next Work Programme? Which related innovation aspects could reach market deployment within 5–7 years?
- What are the key assumptions underpinning the development of these areas (research & innovation, demand side and consumer behaviour, citizens' and civil society's concerns and expectations)?
- What is the output that could be foreseen, what could the impact be, what would success look like, and what are the opportunities for international linkages?
- Which are the bottlenecks in addressing these areas, and what are the inherent risks and uncertainties, and how could these be addressed?
- Which gaps (science and technology, markets, policy) and potential game changers, including the role of the public sector in accelerating changes, need to be taken into account?
- In which areas is the strongest potential to leverage the EU knowledge base for innovation and, in particular, ensure the participation of industry and SMEs? What is the best balance between bottom-up activities and support to key industrial roadmaps?
- Which areas have the most potential to support integrated activities, in particular across the societal challenges and applying key enabling technologies in the societal challenges and vice versa; and cross-cutting activities such as social sciences and humanities, responsible research and innovation including gender aspects, and climate and sustainable development? Which types of interdisciplinary activities will be supported?

Timeline

On the basis of the meetings held during this time period, each Advisory Group should produce a report by summer 2014 summarizing the responses to the above questions. This consultation represents the first step in a sequenced approach towards the priority-setting for each Horizon 2020 challenge/part. Based on this input, the Commission will enter into a full discussion with Member States, on defining the potential priorities for the work programme 2016–2017, during second half of 2014.

The Commission expects, on the basis of an established list of priorities, to develop the content of the work programme 2016–2017 in first half of 2015 with the adoption and publication of the calls for proposals not earlier than summer 2015.
