The Guild
of European Research-Intensive Universities

Guild mission proposals for the next EU Framework Programme for Research and Innovation

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Introduction

This document presents proposals for missions for the EU's next Framework Programme for Research and Innovation (FP9) stemming from the academic communities of The Guild's nineteen member universities. The five potential missions included in this document were selected from a total of 40 proposals received through an internal consultation process. The selection was conducted by five presidents from Guild universities, and the mission proposals were finalised in collaboration between researchers from across our network.

We proposed three parameters for the description of the missions: (1) the impact of the mission on society and science, and how it would support the EU's contribution to the Sustainable Development Goals of the UN (SDGs), (2) how it relates to the concerns and well-being of European citizens, and (3) its potential to foster interdisciplinary collaboration. We would like to thank all the academics in our network who contributed to the creation of these proposals.

The proposals are intended to feed into the debate on what kind of research and innovation (R&I) missions could be introduced in FP9. We hope that they will inform the European Commission on how missions could be formulated, and how acute research questions could translate into missions that inspire citizens. We also hope that our proposals will feed into the wider debate about the missions, which we will continue to engage with in 2018. These proposals are published together with a policy paper that provides a deeper reflection on the challenges and opportunities fostered by the mission-based approach for research and innovation.

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Mission 1 - Restoring the cultural authority of science

A. **Description of the mission**

Eight years after president Obama pledged to "restore science to its rightful place," it is becoming clear that science is increasingly embroiled in interrelated institutional, epistemic, and legitimation crises. The capacity of scientific institutions to sustain procedures for accumulating knowledge and establishing reliable and valid evidence is being questioned. The mechanisms by which science self-corrects and assures high quality findings, notably through the peer review system, are challenged by several factors, including the high pace of knowledge production, increased demand for societal relevance, and by national and institutional incentive structures, and performance measurement schemes which may divert trajectories of academic work. Claims that "most published research findings are false" (Ioannidis 2005), or that the current research system leads to a "natural selection of bad science" (Smaldino & McElreath 2016), testify to the crisis. When institutions and processes of science are perceived to be faltering, then public trust will diminish (Sarewitz 2016).

What is at stake is no longer the grand Modernist and Enlightenment image of science driving inexorably forward and bringing forth social benefits. Decades of research have readily shown science and technology to be sources of profound questions, uncertainties, undesirable impacts, and social and ethical dilemmas themselves (Beck 1992; Shapin 2010). What is at stake is the overall status of knowledge – including its continuous contestation – in society. What is needed is not only the invigoration of concerns for sound norms within science, but also a broader mentality of critical reflection, reasoning, and precedence of evidence in society; a 'science culture', in other words (Bauer et al. 2012). A vibrant science culture requires nurturing at all levels of formal education, but might, importantly, also be promoted through new, more inclusive, kinds of collaboration and knowledge sharing captured in the notion of Open Science (EC 2016).

The mission of restoring the cultural authority of science cannot be entertained by any one country or organisation, but requires concerted research activities addressing the governance and practice of science, and the role and responsibilities of science in society across institutions and countries. Building on previous actions within the 'Science with and for Society' programme and its predecessors, and capitalising on the current mobilisation related to the revision of the European Code of Conduct for Research Integrity, the EU is in a strong position to lead this mission.

B. **Impact of the mission on society and science: What could be achieved through the mission? Which UN Sustainable Development Goals would the mission address? What would success look like, and how could it be measured?**

Deterioration of the validity of knowledge claims and the declining cultural authority of science have severe impact on the quality and legitimacy of individual and public decision-making, as well as on the ecosystems of innovation. Sound, evidence-based knowledge and a strong science culture are the nuts and bolts of any attempt to address current challenges and successfully achieve global goals of sustainable environmental, social, democratic, and economic development.

Restoring the cultural authority of science is equally about truth and trust. Evaluating the success of this mission would therefore entail measuring research behaviour (integrity, questionable research practices, and misconduct) on the one hand, and science culture (citizen trust, efficacy, and behaviour) on the other. While some empirical markers exist in both areas (cf. Fanelli 2009; John et al. 2012; National Academies of Science, Engineering, and Medicine 2015; Sturgis & Allum 2004), the development of metrics specifically tailored to the aims of the proposed mission will be necessary (Hicks et al. 2015; Wilsdon 2015).

C. **Interdisciplinarity**

While the proposed mission has obvious relevance across disciplines, the research efforts needed to support its implementation would particularly call for the integration of perspectives from the history, philosophy and sociology of science, as well as science and innovation policy, research policy and evaluation, and science and technology studies, to investigate the systemic and institutional roots of the current crisis of science.

Moreover, perspectives from social psychology, political science and science communication would be needed to examine properties of existing science cultures and the conditions for restoring the cultural authority of science.

D. **How is the mission relevant to citizens?**

This proposed mission concerns the norms and professional standards that inform and direct research behaviour and, in turn, influence the validity of scientific knowledge claims. But it also concerns the cultivation of a “knowledge society” (Stehr 1994), which is dependent on its citizens to embrace what Irwin (1995; 2001) refers to as “scientific citizenship.” Ultimately, the dynamics of science culture are determined as much by societal actors as by scientists, and the ability of science to align with societal values, needs, and expectations (von Schomberg 2013; Rome Declaration 2014) is likely to be interrelated with its cultural authority. Citizen co-creation of science culture is, therefore, a core concern, and the EU can draw on decades of experimentation within the area of “public engagement with science” (Stilgoe et al. 2014) to inform activities related to the proposed mission. Likewise, current efforts to foster an Open Science agenda in Europe will provide an interesting opportunity for exploring the interaction of trust and truth in the public arena.

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Mission 2 - Leaving a sustainable city in a sustainable landscape to our children

A. **Description of the mission**

More than half of all people live in cities occupying only 3% of all Earth's land, but accounting for 60-80% of energy consumption, and 75% of carbon emissions. By 2050 80% of all Europeans are expected to live in cities, and our ecological footprint will be even bigger.

The existing structures are already reaching their capacity. Regions around cities are transforming into anonymous food production areas, working on efficiency but threatening biodiversity. At the same time global developments like the Paris Agreement set ambitious goals that Europe will not reach if we do not drastically adjust our course. Therefore, there is an urgent need to reshape the city, its infrastructure and its surrounding region, into a healthy ecosystem.

Cities and the regions that surround them constitute the ideal 'Living Lab' where new solutions can be found and implemented. They are hubs for ideas, culture, science, productivity, social development, and much more. To change, they must be open to innovations to ensure more sustainability, decrease pollution and gas emissions, improve transportation, future-proof food systems, use more green energy, develop better digital systems for improved connectivity between actors, etc. The city and the region are 'the hand' and 'the glove' that have to be developed together.

In the city of the future there is a strong involvement of humans in e.g. energy transition next to technical solutions. We do not only have to invest in more efficient electrical cars, but people will have to learn how to drive differently; or find other traveling solutions. The focus should be on city inhabitants when they are at home, but also when they travel elsewhere. Tourists visiting the city will need to comply as well.

Another important aspect of the city and the region of the future is the transformation to a sustainable food system. A consumer-centered diet is key to secure human health and nutrition. Shortened food supply chains, and healthy and convenient food solutions are needed to meet changing lifestyle trends. Major health issues, including obesity and anti-microbial resistance, and minimising the environmental and climatic footprint of food production, should be in focus. These developments will have a considerable effect on the relation between the city and the region. This calls for integrated solutions and the options are there.

Regions around cities act as ecological buffers and provide various goods and services. These regions have to be managed in a way that leads to the development of sustainable biodiverse landscapes, composed of a mosaic of natural, semi-natural and cultivated ecosystems.

B. **Impact of the mission on society and science: What could be achieved through the mission? Which UN Sustainable Development Goals (SDGs) would the mission address? What would success look like, and how could it be measured?**

The mission's success should be measured in selected city-regions now and in 2030, using a range of indicators and selecting objectives within the SDGs framework: including climate emissions, food provisioning and nutrition, the health of citizens, transport systems, and biodiversity.

The topic will be relevant for following SDGs:

Goal 11: Make cities inclusive, safe, resilient and sustainable
Goal 13: Take urgent action to combat climate change and its impacts
Goal 6: Ensure access to water and sanitation for all
Goal 2: Zero hunger
Goal 3: Good health and well-being
Goal 7: Affordable and clean energy
Goal 8: Decent work and economic growth
Goal 9: Industry, innovation and infrastructure
Goal 12: Responsible consumption and production
Goal 15: Life on land

See also the recent 2017 UN report: "Implementing the new urban agenda by strengthening urban-rural linkages. Leave no one and no space behind."

C. **Interdisciplinarity**

In the city and the region of the future, all crucial societal elements are optimised through engagement of all actors and stakeholders: close cooperation with academia ensures evidence-based political leadership, and science supports citizen-driven social innovations. Cities use innovative models for involving citizens, communities and other stakeholders at the right stages in the political processes.

- Smart Specialisation Strategies are developed based on research, innovation hubs and co-creation spaces to bring value for the benefit of all citizens.
- There is sustainable citizen's engagement and empowerment in creating innovative solutions for important social issues and connecting urban, peri-urban and rural areas.
- A sustainable infrastructure for e.g. energy, water, food and waste is present.
- And sustainable health is realised for all citizens.

D. **How is the mission relevant to citizens?**

It is obvious that this mission is relevant to citizens. There is a real risk that today's young adults – the most educated generation we ever had – may end up less well-off than their parents. Providing jobs, housing, social services, and education in a safe sustainable environment is difficult, but cities and regions with their infrastructure, ideas, and access to financial and political capital, are particularly well equipped to address that challenge. They can act much quicker and more ambitiously compared to countries. The transition to a green circular economy will affect all citizens. This mission needs a strong focus on citizen participation, evidence-based policymaking, networking, social and technical innovation, as well as in connecting city centres with their wider regions.

Mission 3 - Eradicating Europe's digital divides

A. **Description of the mission**

Digitalisation fundamentally changes the way we live and work and the principles of modern democracy. The tools we use in our personal and professional lives are almost unrecognisable compared to those that existed 50 years ago. We can anticipate even more of a shift in the ways our societies operate, and the way we live our lives in the next 50 years. However, this shift has not affected all of Europe equally – there is a growing digital divide.

The digital divide is not only a difference in access to, but also a difference in the capacity to make use of Information and Communication Technology (ICT). The European digital infrastructure has become one of the most important fundamentals of our economy and society, but the digital divide separates individuals, communities, businesses, regions and countries into new 'haves' and 'have nots'. At the same time, key sectors like trade, education, healthcare, agriculture, government, finance, media, and even households, are increasingly more dependent on a well-functioning ICT infrastructure and relevant ICT competence. Digital platforms have become the foundation for participation by institutions and actors across society, and digital literacy is a precondition for cultural production and innovation.

Research has documented how changes in the labour markets of developed economies due to digitalisation have also changed the skill demands of many jobs. Work environments across the continent are becoming increasingly technology-rich, addressing ill-defined problems that require multidisciplinary teams and approaches. The European Commission document "A Digital Single Market Strategy for Europe" states that "shortages of ICT professionals in the EU could reach 825,000 unfilled vacancies by 2020 if no decisive action is taken," and that "[digital] skill levels need also to be raised among employees in all economic sectors and among job seekers to improve their employability."

There are also rising inequalities globally, including enormous disparities in opportunity, wealth, and power. Recent surveys among citizens in developed societies indicate a declining level of trust in political and media institutions, which challenge democratic processes. There is a large digital skills gap between citizens across the EU. In Bulgaria and Romania, only 26-28% of the adult population (age 16-74) have basic or above basic overall digital skills, compared to 77-86% in the Netherlands, Denmark and Luxembourg.[1] This mission aims to eradicate these 'skills gaps' through a combination of research, education, and innovation strategies.

The competences needed to succeed in the labour market must be developed throughout the educational system, providing students with both the specialised and generic competences required. Such changes call for major transformations in the ways in which institutions combine disciplinary knowledge with new and emerging ICT knowledge. These developments need to build on the coherence of research in disciplines, digital knowledge areas and educational studies. Without integrating these subject areas, we risk not building the capacities needed for advancing democratic development and creating and sustaining jobs and industries.

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[1] Eurostat (2016). *Individuals who have basic or above basic overall digital skills by sex*. [Online]. Available from: https://goo.gl/cBQzkf [Accessed 20 November 2017].

The overall goal is to: Eradicate the digital divide and 'skills gap' within and across European countries by 2026. Challenges regarding work, basic skills, and democracy, as described above, will be reduced. The mission primarily addresses UN Sustainable Development Goal (SDG) 4, "Quality Education," SDG 10, which aims to reduce inequalities, and SDG 9 "Resilient infrastructure."

1. Democratic development: Education as the foundation for informed citizens and for job creation

The increasing digital gaps in Europe and elsewhere need to be addressed by multiple measures. The EU must prioritise reforming educational systems and the tools for competence development. ICT developments play a role in democracy by providing an opportunity to bridge the gap and strengthen the ties between democratic institutions and society. Recent developments in e.g. Internet of Things (IoT) and Big Data can help policymakers make more informed decisions, while blockchain technology may allow for more public engagement. However, the development of democracy is not only a question of technological solutions but also of facilitating digital competences and citizenship among all members of society, which means the formation of values, norms and institutions that all citizens' trust. By taking a leading role in these developments worldwide, Europe can make sure that the ICT solutions created meet the principles and requirements of a democratic society, preserving liberty, privacy, autonomy, non-discrimination and transparency.

2. Research-based Education

Developing digital proficiencies and eradicating the digital divide require a coordinated effort in both education and research. We need to prepare and motivate teachers across the educational spectrum to provide students with necessary digital competencies – including insight into computer programming – to become educated citizens who can work effectively with digital technology in the future. This requires educational programs based on a combination of disciplinary research, computational and data science research, and educational research – areas that explore, among other things, how people learn and activate knowledge – to inform new educational content and methods. This should lead to 'state-of-the-art skills' and (technological) tools for teachers that significantly contribute to better and more efficient education and more adaptive learning methods.

Digital transformation requires new skills of workers throughout their careers. Access to affordable and relevant post-secondary education is therefore essential to continually transform the workforce. Digital advances and computational methods will revolutionise research, innovation, education, and have significant impact on the labour market. However, such developments may be increasingly localised and may lead to rapidly growing differences unless action is taken. The mission aims at eradicating this 'skills gap', which can also be seen as a digital divide by education and research. Training the next generation of teachers and researchers in all domains based on new digital skills should be seen as one of the most important factors for placing Europe at the forefront of the digital revolution, and for creating equal opportunities across regions and nations in Europe.

3. Ethics and the digital divide

Ethical principles and critical thinking constitute the foundation for a life permeated with digital technologies since it has fundamental consequences for responsible research and innovation processes, as well as for all forms of implementation. The fact that millions of European citizens do not use ICT solutions on a regular basis (or not at all) represents a major challenge related to basic ethical principles for societal cohesion as well as for economic development. The consistent implementation of digital solutions for society also relates to ethical principles for scientific research (e.g. informed consent and transparency) that need to be revisited and reconsidered. Fundamental ethical questions are raised by new digital technologies, such as the role and responsibilities of intelligent machines, and access to and ownership of data. Europe should become a forerunner in ethically reflecting on the effects of the processes of digitalisation, including foresight, and early warning and monitoring.

4. Technology and digitalisation

Unequal access to technology and communications represents an important aspect of the digital divide. For example, (mobile) broadband is available to (86%) 71% of European homes in urban areas, but only to (36%) 28% in rural areas. This limits the possibility to innovate in e-agriculture, e-farming, e-commerce, e-working and e-government across Europe. In addition, the development of an effective e-infrastructure is essential for effective e-education innovations, which are needed to build digital competence among citizens, students and workers. The digital economy depends on affordable access to effective communication, computing, data flow and data storage. Thus, supporting research and innovation in e-infrastructure is an essential part of a strategy to eradicate the digital divide.

In addition, data-security and privacy-protection play an ever more important role in a digital world. We cannot afford an erosion of the trust we have in the digital infrastructure, since trust is a condition for normal economic transactions and inter-human communication. Security relies on both technological solutions and users' competencies. To build a resilient digital infrastructure, promote inclusive and sustainable industrialisation, and foster innovation, it is imperative to provide data-security for all sectors of society. Also, the development of sufficient competencies among relevant user groups can be seen as the basis for the advancement of businesses, for science, and for society in general.

B. Impact of the mission on society and science: What could be achieved through the mission? Which UN Sustainable Development Goals (SDGs) would the mission address? What would success look like and how could it be measured?

1. Democratic development (SDGs 16, 17)

By 2026 the innovation processes of digitalisation are responsible, transparent and ethically well-argued. The impact of this mission would be measured indirectly by looking at trust and confidence levels in political governance, the European ICT infrastructure, and by incorporating academic studies that focus societal problems.

2. Research-based Education (SDGs 4, 8, 9, 10)

By 2026 Europe has eradicated the digital divide and 'skills gap' within and across countries. Challenges regarding work, basic skills, democracy as described will be reduced.

3. Ethics (SDGs 5, 16, 17)

By 2026 the innovation processes of digitalisation are responsible, transparent and ethically well-argued. The impact of this mission would be measured indirectly by looking at trust and confidence levels in political governance, the European ICT infrastructure, and by incorporating academic studies that focus societal problems.

4. Technology (SDG 9)

Effective and secure communication, computing, and data storage, are available for everyone. There is also widespread access to new business opportunities, and careers in computing, data storage and security. This, in turn, leads to a general boost for innovation in high-tech fields due to the availability of communication, super-fast computing and data storage.

5. Behavioural change (SDGs 9, 16)

By 2026 citizens, companies and public bodies on all levels in Europe are fully aware and educated to take responsibility for (their own) cybersecurity and -privacy, equivalent to the security and privacy measures citizens take in the physical world. Awareness and measures taken by citizens and employees have become common use: like locking your front door when leaving home. It could be measured by significant reduction of attacks – and their impact – by hostile hackers.

6. Infrastructure

Security and privacy protection should also be ensured within the ICT infrastructure. This includes malware detection and removal, intrusion detection and prevention, trustworthiness of networks and hardware, software security, security of SCADA/industrial control systems (ICS), and secure operating systems.

C. **Interdisciplinarity**

The proposed mission requires an interdisciplinary as well as transdisciplinary approach. It would require the contribution of the hard sciences, especially information and communication sciences, informatics, mathematics, and the social sciences and humanities, including among others, sociology, political science, economics, educational and learning sciences, media, law and cultural studies. These would all have an important role to play in this mission.

Generally, by applying a notion of basic and transferable skills for knowledge and learning, the humanities, and the social and learning sciences provide rich traditions of insight into basic properties, practices, and knowledge potential through writing, imaging, movement, and mediated and interpersonal communication. In a situation in which competencies and media platforms are shifting rapidly, it is vital to connect the skills for one particular technology and platform to basic and transferable skills.

For example, the human, and the social and learning sciences' contributions to a mission for closing the digital divide would include: (1) concepts for the further advancement of basic and transferable competences to foster knowledge creation in situations where competencies and media platforms are shifting rapidly; (2) specific digital tools for learning that are based on research insights from the three aforementioned science areas.

Similarly, the learning, educational, natural and computational sciences should cooperate to educate the teachers of the future, and to enable the flow of computational scientists and innovators by: (1) preparing students to work with intelligent machines by lifting the digital competencies of teachers throughout Europe, through strong, computational research, and innovation clusters tied to their local communities and cultures; (2) educating a new generation of digitally competent students with cross-disciplinary experience who are motivated to establish research and industry throughout Europe.

D. **How is the mission relevant to citizens?**

Digitalisation is a process everyone is personally connected to and, thus, all citizens will be affected.

A participation process must be developed to safeguard a researcher's ability to ask the right questions. This same participation process must also foster citizens' engagement with research processes using well-established and new methods, e.g. early-phase co-design activities, roundtables, and scenario workshops, among others. Moreover, citizens can help researchers generate data about everyday life in Europe (whilst ensuring that privacy rights are upheld), and in the formulation of the possible consequences of research results.

For example, by focusing the mission on education, interdisciplinary knowledge, and educational research (in a broad sense) across the whole educational spectrum, future generations will be able to handle and develop the digital information society. Projects done in cooperation with schools at different levels will serve as a meeting arena for citizens and researchers.

Mission 4 - Personalised prevention, precision medicine and healthy ageing: two more healthy years for all EU citizens by 2025

A. **Description of the mission**

"The promise of PM is so great, it is almost daunting. It seems futuristic – a departure from traditional medicine that could be difficult to embrace."

- Professor Ara Darzi, Lord of Denham & Dr Victor Dzau[1]

Precision medicine is a rapidly emerging approach based on identifying subgroups of patients with distinct mechanisms of disease, or particular responses to treatments. This approach enables doctors and researchers to identify and develop treatments that are effective for particular groups of patients. Ultimately, precision medicine will ensure that the right patient gets the right treatment at the right time, in contrast to the current 'one-size-fits-all' approach. It is widely expected that precision medicine will have a disruptive effect on future healthcare, with significant impact on healthcare providers, the pharmaceutical industry and the medical technologies supply chain. Technological advances such as DNA-sequencing would also allow for personalised prevention leading to healthy ageing.

In addition to the benefits precision medicine will bring to patients, its economic impact promises to be significant. The global drug market is now projected to grow to $1.4tn by 2020. However, a significant proportion of first drugs prescribed, ranging from 62% (antidepressants) to 25% (cancer), are ineffective, imposing significant costs on healthcare systems. In the UK alone, of the £124bn per annum spent on healthcare, medicines account for £12bn or 10% of the NHS budget. In Scotland alone, the NHS spent £150m more on drugs in 2014/15 than in 2012/13. The savings across Europe will be massive in the context of national healthcare budgets. The adoption of precision medicine will be a key factor in managing the increasingly unsustainable level of spending on medicines due to an ageing population, and provide incentives for the pharmaceutical industry to repurpose existing or failed drugs and develop companion diagnostics.

A precision medicine approach will reduce development times, lower failure rates, and significantly decrease development costs. As the aforementioned technological advances provide insight into diseases 'beneath' the clinically presented symptoms, allowing for an early disease subtyping, the 'correct' pharmaceutical intervention may already be selected much earlier than in the conventional approach based on empirical response to sequentially tested pharmaceutical interventions.

Globally, there are many initiatives underway to create national implementation strategies for personalised prevention and precision medicine, to translate science to clinical practice. However, many of these efforts lack the collaboration that is essential to come to an integrated optimised approach to precision medicine. The FP9 mission provides an unprecedented opportunity to

[1] Dzau, V., Ginsburg, G., Finkelman, E., Balatbat, C., Flott, K. and Prestt, J. (2016). Precision Medicine: A Global Action Plan for Impact. [Online]. In: *World Innovation Summit for Health*, Doha, 29-30 November 2016. Available from http://www.wish-qatar.org/wish-2016/forum-reports [accessed 20 November 2017].

accelerate the pace of discovery and translation into clinical practice across Europe, and provide global leadership of precision medicine.

B. **Impact of the mission on society and science: What could be achieved through the mission? Which UN Sustainable Development Goals would the mission address? What would success look like and how could it be measured?**

- Good Health & Wellbeing (SDG 3): There would be a direct benefit for patients across a very broad range of disease prevention and chronic diseases, which are the leading cause of mortality and morbidity in Europe, and will impose an even larger burden in the future.
- Decent Work and Economic Growth (SDG 8): The mission could lead to the creation of quality jobs and skills for the life sciences supply chain, and reduce the economic burden on national healthcare systems in the EU. Chronic diseases depress earnings, workforce participation & productivity, and increase early retirement, job turnover and disability.
- Industry, Innovation & Infrastructure (SDG 9): Successful implementation of personalised prevention and precision medicine will drive innovation and collaboration between academia, industry and healthcare providers. It will also reduce the number of prescribed pharmaceuticals, that form an ecotoxicologial burden on the European bodies of surface water.
- Reduced Inequalities (SDG 10): There are currently inequalities around access to expensive modern drugs, such as cancer treatments, due to affordability and limited efficacy. This inequality would be reduced by allowing medicines to be prescribed to those who will definitely benefit from them (which would be more affordable and effective).

C. **Interdisciplinarity**

Successful implementation of personalised prevention and precision medicine will require collaboration between academia, industry and healthcare providers.

Disciplines will include (but will not be limited to) disease-specific researchers (basic science and translational), clinical medicine, genomics, epigenetics, metabolomics, imaging, clinical physics, bioinformatics, health economics, medtech and diagnostics, engineering, data science, machine learning, and business. The aspects of healthy ageing will involve geriatricians, eHealth experts and social scientists. The implementation of preventive analyses and treatment will also require participation of patient groups, on a psychological and sociological level to ensure that implementation will optimise patient well-being.

D. **How is the mission relevant to citizens?**

The mission would be directly relevant to citizens as there would be a direct benefit for patients across a very broad range of chronic diseases. Citizens would be engaged with the mission through focus groups, healthcare advocacy organisations, and public engagement. Personalised prevention and precision medicine are new areas of science, and both patients and citizens have understandable concerns about providing and authorising the sharing of their genetic and personal information. The 2016 World Innovation Summit for Health report on Precision Medicine identified that the persistence of these concerns arguably presents the most significant barrier to precision medicine's promise.

Topics of interest to citizens would therefore include the benefits to patients, as well as delaying and preventing chronic diseases, but also the use of patient data, the ethics of genome sequencing, the role of industry in healthcare, access to expensive new treatments, etc. The patient will also take over important roles conventionally held by the caregiver, such as the periodic measurement of health through sensors and point-of-care technology. This will lead to radical changes in the analytical information content of the resulting data that now will be collected by the major untrained stakeholders in the healing process.

Mission 5 - Take arms against anti-microbial resistance (AMR): halving the number of infections and extra deaths by 2027

"Take Arms against a Sea of troubles, And by opposing end them."

- William Shakespeare, *Hamlet*

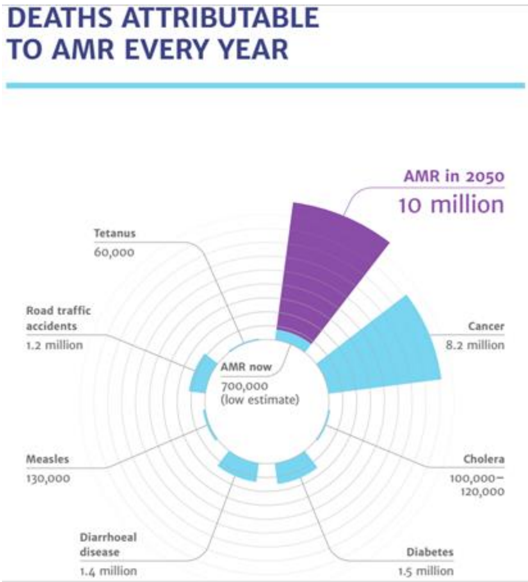
A. Description of the mission

The discovery of penicillin by Alexander Fleming in 1928 marked the dawn of the antibiotic age and ignited the modern era of drug discovery. It revolutionised healthcare, and to this day these drugs remain the cornerstone in the treatment and prevention of infectious diseases. It also enabled many important medical breakthroughs including safe surgical procedures, organ transplantation and chemotherapy for cancer treatment. Unfortunately, the emergence of resistant bacteria was detected soon after the first anti-microbials were introduced.

In Europe, where by 2050 up to 30% of the population will be 60 years or older, the demographic transition across lifespan will have a decisive impact on health care, leaving patients more susceptible to infections. Healthcare will allow for more invasive and complex surgical therapies using medical devices. The number of immunocompromised patients will increase. In consequence, healthcare associated infections will rise steeply. At the same time human and animal migration and globalisation will increase the intercontinental spread and the fast rates of resistance development of pathogenic microorganisms, which threaten public health. Up to 90% of the antibiotics used in livestock farming end up in the environment, with unknown consequences for water, soil, and biodiversity. Disappointingly, a very low number of new antibiotics have been discovered and/or developed due to a multitude of problems: poor efficacy, delivery issues, difficulties in setting up clinical trials and the huge costs associated with these, and generating an adequate return on investments into the development of antimicrobials.

We have to invest in innovative smart antibiotics, personalized medicine, novel diagnostics, alternative therapies and innovative drug delivery, preventive measures, and (targeted) treatment of unbeatable infections caused by multi- and pan-resistant microorganisms. If we do not act now we risk many millions of **extra** deaths worldwide by 2050. This AMR threat is eminent and affects us all; it calls for an immediate, coordinated and coherent multidisciplinary and inter-sectorial approach.

The goal of this mission for the EU is to reduce in the next 10 years, the more than 30 million infections and 1 million extra deaths by 50%.



B. **Impact of the mission on society and science: What could be achieved through the mission? Which UN Sustainable Development Goals would the mission address? What would success look like and how could it be measured?**

This mission mainly targets the SDG 3 - ensure healthy lives and promote well-being for all at all ages. AMR is the consequence of societal changes. Due to international movement of people, upscaled non-sustainable industrial developments (e.g. livestock and food production) as well as lack of access to pure water supply and emission of antibiotics into the environment and the food chain, AMR has direct and an indirect influence in SDG 3 and in SDGs 6, 9, and 12. SDG 4 and 9 are required to combat AMR.

We must ensure that we will always have strategies to inhibit further development of AMR. We need antibiotics against any occurring multi-resistant pathogenic bacterial strain. This requires a continuous inter-sectorial effort, because bacteria will find ways to get resistant again. We are never done! This was the mistake we made in the past. We trusted we had enough effective antibiotics, and the new development slowed down significantly.

C. **Interdisciplinarity**

Novel intersectoral strategies need to be developed that simultaneously address:

- Antibiotic development from discovery and synthesis towards approved drugs: e.g. microbiology, molecular biology, biotechnology, bioengineering, nano-biotechnology, materials science, biostatistics, biochemistry, pharmacy, medicinal chemistry, natural compound. In addition, microbial/evolutionary genetics.
- AMR prevention: e.g. epidemiology of infectious diseases, biomathematics, stewardship, behavioural sciences, psychology, global health policy, vaccinology, veterinary microbiology, environmental & marine biology (plus fisheries).
- Patient care: e.g. medical microbiology, novel (personalised) medicine and diagnostics, eHealth, IC-care, innovative implant-technologies, targeted delivery (incl. localised activation of anti-microbial agents).

Facing off transmittable AMR **needs a paradigm-change in healthcare**, switching from production-economic to prevention-economic incentives to promote health-span. Systems health research (former public health), combining different scientific disciplines as well as co-creative collaboration with partners outside academia (industry, politics, NGOs), is a *conditio sine qua non*. Finally, boundaries between frontier-led research and clinical/translational research need to be overcome, reaching out to problem-solving implementation science.

Future implementation of the results of such cutting-edge research requires a solid understanding of the wider societal context of AMR, leading to a call to strengthen the social sciences and humanities (SSH) agenda. **SSH research provides essential knowledge** regarding social and structural drivers of AMR. Historical analyses of AMR show how governance and health system failures have led to, and continue to feed, AMR.

D. **How is the mission relevant to citizens?**

In Europe and throughout the world, citizens will be safe from infections due to drug-resistant microbes. Modern medical treatment will only be possible if novel and smart antibiotics and antimicrobial therapies are working, and the increase of AMR is not accepted. There will be no risk of outbreak of life-threatening diseases that cannot be cured by antibiotics. Regions, countries and as a major goal the whole EU will be maintained free of life-threatening infections due to multi- and pan-resistant microorganisms.