

# TRANSFORMATIVE PERSONAL HEALTH TECHNOLOGIES IN 2040



**POLITECNICO**  
MILANO 1863

TECHNOLOGY FORESIGHT

**Paola Antonietti**  
**Cristiana Bolchini**  
**Francesco Braghin**  
**Simona Chiodo**  
**Giuliana Iannaccone**



# GOALS

- ◇ advance our path towards technology foresight activities to empower our community and facilitate our industrial partners
- ◇ challenge our vision on important matters
- ◇ promote and increase awareness on Politecnico di Milano's expertise in areas that can be further valorised

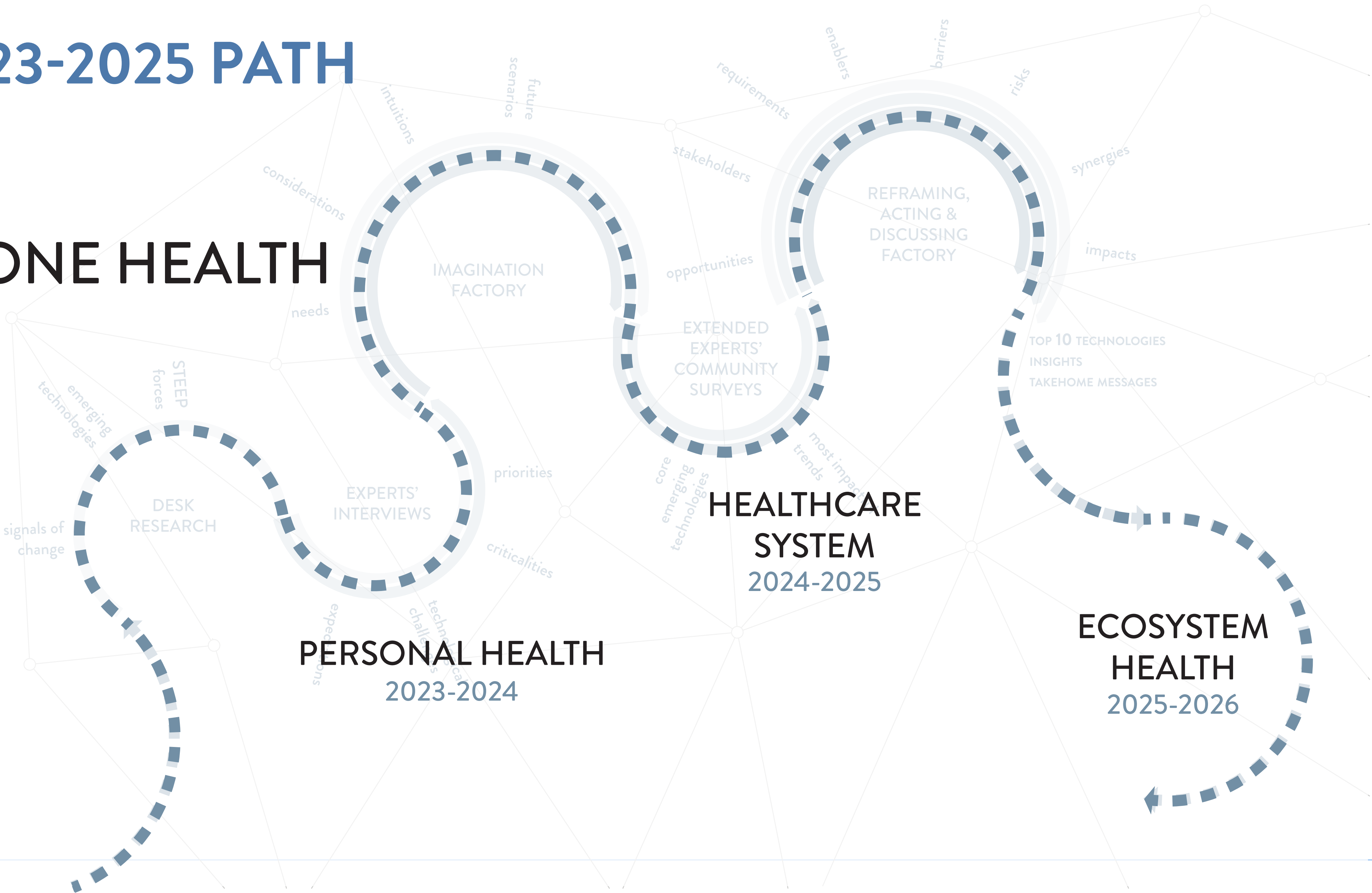
life sciences ► health





# 2023-2025 PATH

## ONE HEALTH



# TECHNOLOGY FORESIGHT

**detect** “weak signals” of change that might not be already part of ongoing trends

**explore** possible futures

**highlight** pre-conditions and necessary ecosystems to facilitate new technologies

**evaluate** enablers & barriers towards desirable futures

**support** innovation and technology transfer processes

**highlight** strategic medium/long-term choices



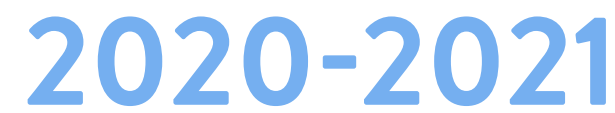
# TECHNOLOGY FORESIGHT @ POLIMI

- ◇ leverages POLIMI's community **independent** expertise
  - » network of academic/industrial experts
- ◇ explores medium/long-term horizon to investigate technologies' role
  - » opportunities, requirements, expected impact and risks
- empowers a forward-thinking perspective
- informs key decision-makers

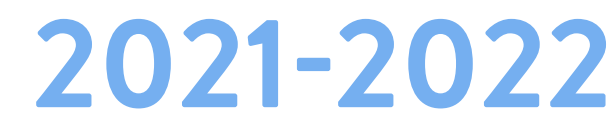


TECHNOLOGY FORESIGHT @ POLIMI

Quale impatto sugli obiettivi di sviluppo sostenibile?



## Come ci muoveremo nel 2035?



Come vivranno ed interagiranno le persone nel 2035 per perseguire il proprio benessere?

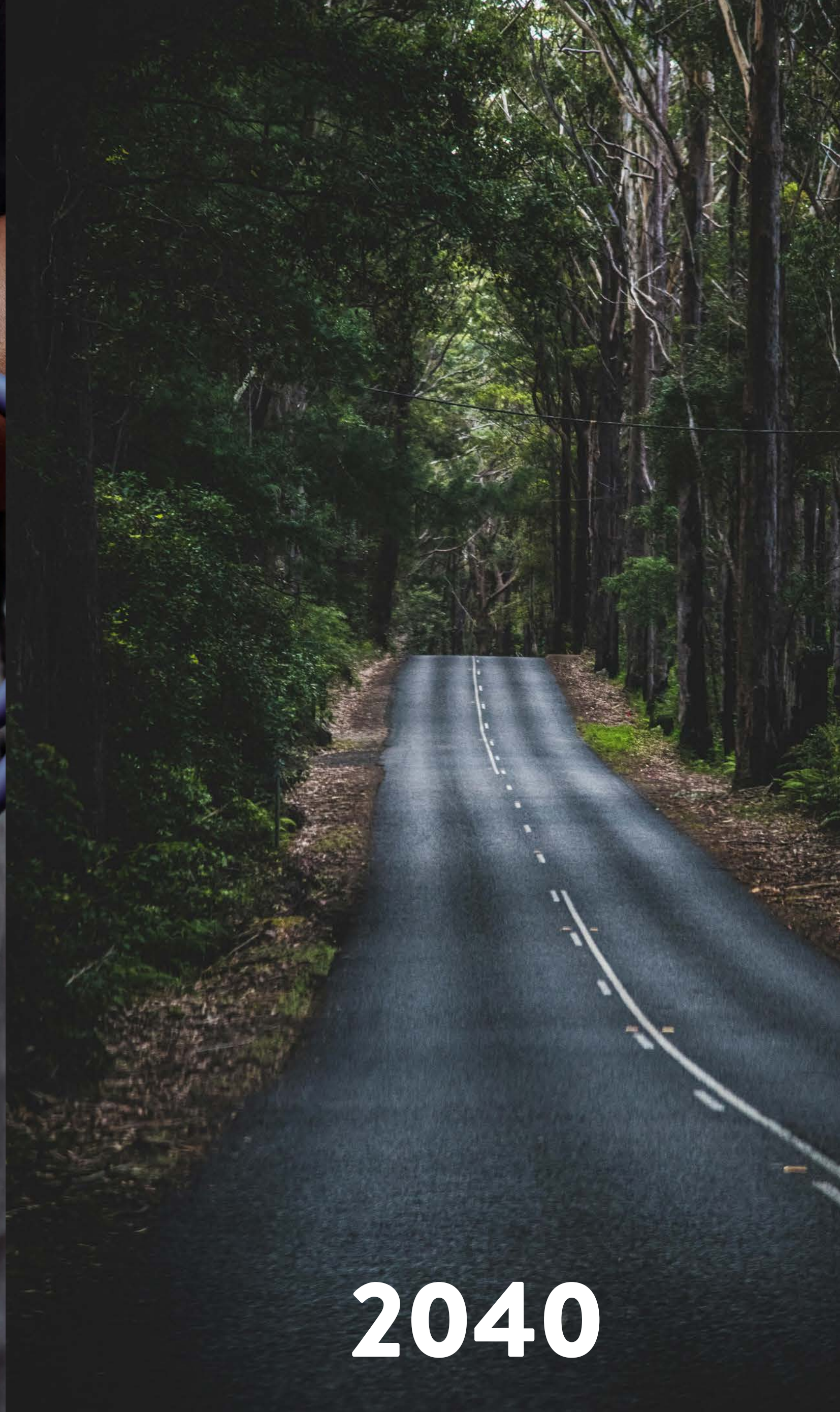






**HEALTH**

image credits: <https://rb.gy/bb7tmg>



**2040**

image credits: <https://tinyurl.com/yey33naj>



**PERSON**

image credits: <https://shorturl.at/VRllw>





**WHAT TECHNOLOGICAL ADVANCES  
WILL BE MORE TRANSFORMATIVE IN 2040?**

**HOW CAN OUR RESEARCH CONTRIBUTE TO  
SUCH A TRANSFORMATION?**



**HEALTH**

image credits: <https://rb.gy/bb7tmg>



**2040**

image credits: <https://tinyurl.com/yey33naj>

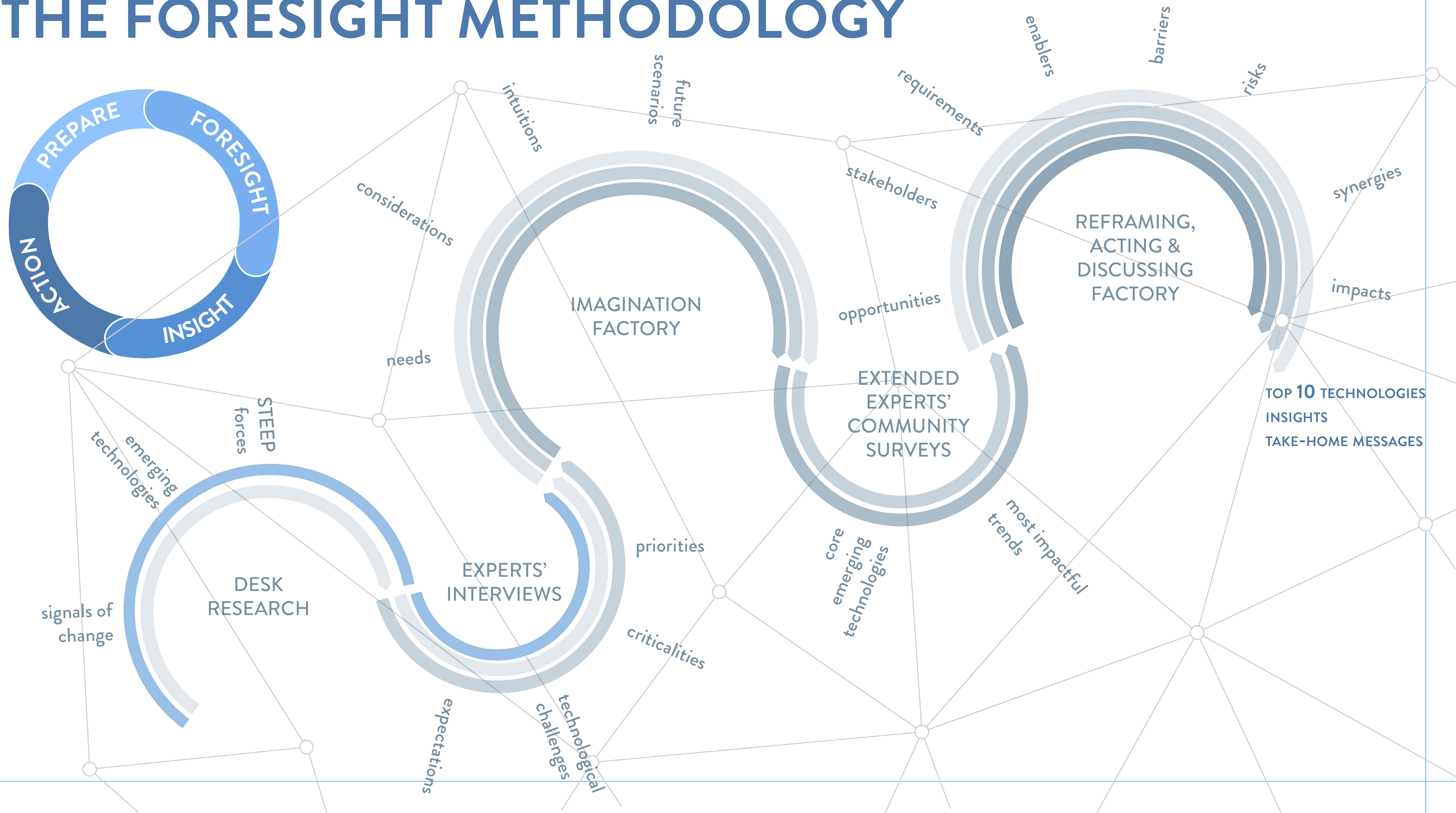


**PERSON**

image credits: <https://shorturl.at/VRllw>

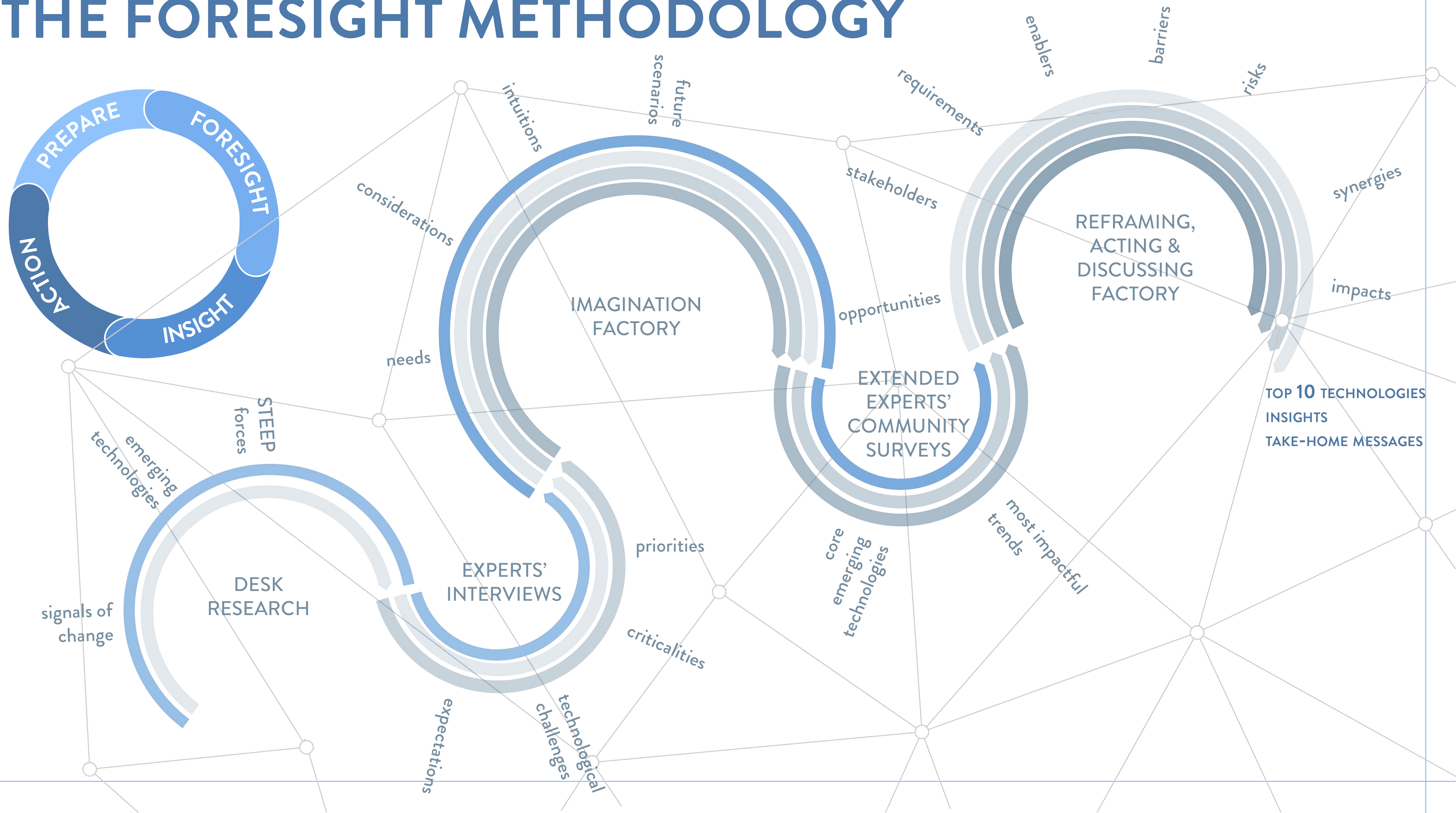


# THE FORESIGHT METHODOLOGY



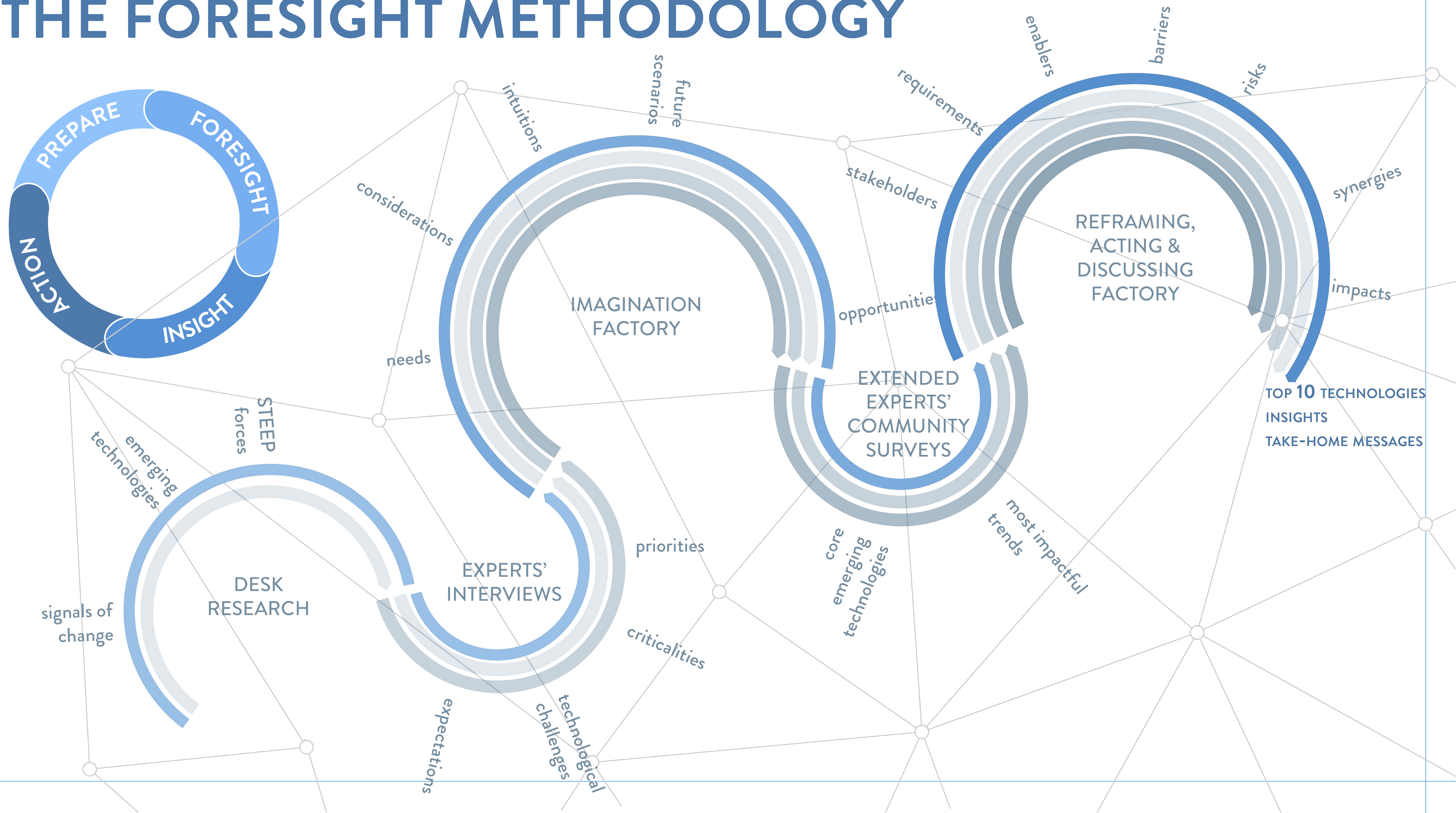


# THE FORESIGHT METHODOLOGY





# THE FORESIGHT METHODOLOGY





# METHOD: INGREDIENTS

- 50 STEEP forces
- 83 signals of change
- 50 technologies
- 24 POLIMI's participants
- 3 physicians

Stacked cards representing STEEP forces:

- SOCIETY** (So 11): DO IT YOURSELF
- TECHNOLOGY** (To 6): ROBOTICS
- ENVIRONMENT** (En 2): ANTIMICROBIAL RESISTANCE
- ECONOMY** (Ec 1): PRIVATIZATION
- POLITICS** (Po 1): SECURITY

**SECURITY**

Are you sure you are safe?

Global public health security is defined as the activities required, both proactive and reactive, to minimize the danger and impact of acute public health events that endanger people's health across geographical regions and international boundaries.

Population growth, rapid urbanization, environmental degradation, and the misuse of antimicrobials are disrupting the equilibrium of the microbial world. New diseases, like COVID-19, are emerging at unprecedented rates disrupting people's health and causing social and economic impacts. Billions of passengers travel on airplanes each year, increasing the opportunities for the rapid international spread of infectious agents and their vectors.

Stacked cards representing signals of change:

- THOUSAND PEOPLE SIGN UP TO HAVE CHIP IMPLANTED IN THEIR BRAIN BY NEURALINK
- NEW BIOMARKER PREDICTS WHETHER NEURONS WILL REGENERATE
- ANCE OF SOME
- BY AN
- ONAL
- UM

Stacked cards representing technologies:

- (HEALTH) DIGITAL TWIN**

Health digital twins are defined as virtual representations ("digital twin") of patients ("physical twin") that are generated from multimodal patient data, population data, and real-time updates on patient and environmental variables. With appropriate use, HDTs can model random perturbations on the digital twin to gain insight into the expected behavior of the physical twin—offering groundbreaking applications in precision medicine, clinical trials, and public health.

Future applications?

References

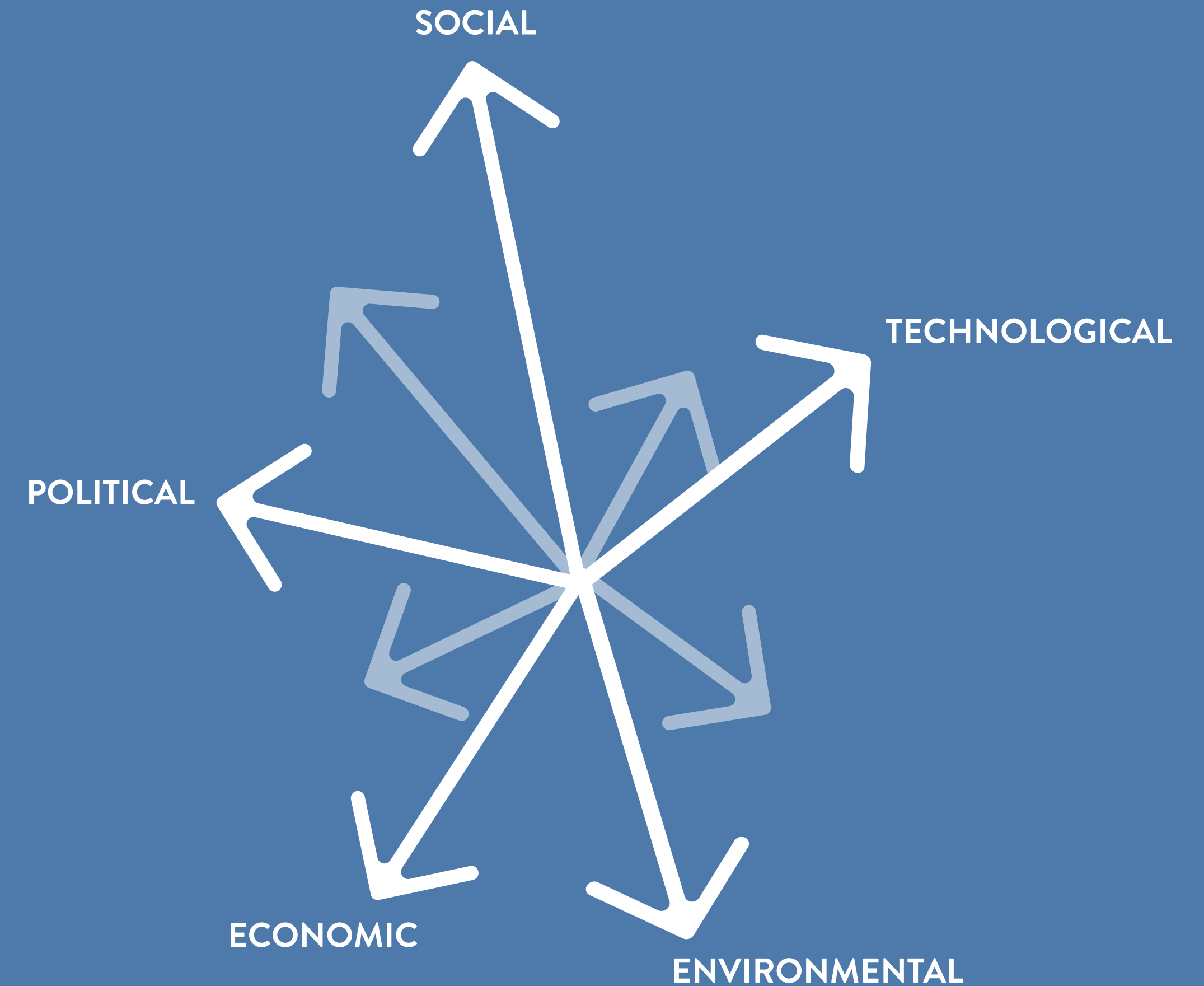
- <https://www.nature.com/articles/s41746-022-00694-7>
- <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9830576/>
- <https://www.siemens-healthineers.com/perspectives/digital-patient-twin>
- <https://www.sciencedirect.com/science/article/pii/S2949723X23000065>



# STEEP FORCES

- ◇ “stable enough” major trends that will possibly shape our future
- ◇ broadly recognised trajectories we observe today
- ◇ referred to a broad spectrum, not context-specific

desk research ► 50 most relevant forces





# STEEP FORCES

## SOCIAL

AGEING DEMOGRAPHIC CHANGES MENTAL HEALTH LIFESTYLES DEEPENING DISPARITIES  
NON-COMMUNICABLE DISEASES BEYOND GENDER MIGRATIONS WORK FROM EVERYWHERE DO IT YOURSELF

## TECHNOLOGICAL

MED(AI)CINE AUTONOMOUS SYSTEMS HYPER-CONNECTED HUMAN ENHANCEMENT  
AVATARS EXTENDED REALITY ROBOTICS DIGITAL TWIN CRYONICS GENETIC CONTROL

## ENVIRONMENTAL

PANDEMICS ANTIMICROBIAL RESISTANCE GLOBAL CLIMATE CHANGES  
EXTREME EVENTS ENVIRONMENTAL DEGRADATION PERMAFROST MELTING POLLUTION  
FOOD WASTE CIRCULAR ECONOMY BIODIVERSITY LOSS

## ECONOMIC

PRIVATISATION MORE PREVENTION, LESS CURE TECH GIANTS' PERVASIVENESS  
NEW SPACES, NEW RELATIONS (UN)PREDICTABLE INSTABILITY INSURANCE MARKET PLAYERS  
DATA EXPLOITATION E-COMMERCE COST OF LIVING INCREASE LACK OF SKILLED WORKERS

## POLITICAL

SECURITY COLLAPSE OF DEMOCRACY WELFARE (TRANS)NATIONAL IDENTITIES  
INFORMATION & CONNECTION GEOPOLITICAL COMPETITION NUCLEAR PATHS GLOBAL COMMONS  
THE RISE OF ETHICAL QUESTIONS STATES LIKE SILOS





# AGEING



## Are we all gonna be Dorian Grey?

Aging is progressive physiological changes in an organism that lead to senescence, or a decline of biological functions and of the organism's ability to adapt to metabolic stress.

Aging occurs in a cell, an organ or throughout the organism with the passage of time. It is a process that goes on over the entire adult life span of any living thing.



## What do we know?

There is much debate among researchers about the mechanisms that contribute to the ageing process. However, it is widely accepted that damage to genetic material, cells and tissues that accumulates with age (and cannot be repaired by the body) is the cause of the loss of function associated with ageing.

Main causes of ageing are genomic instability, telomere degradation, epigenetic changes, loss of proteostasis, impaired perception of nutrients, mitochondrial disfunctions, cellular senescence, exhaustion of stem cells, altered intercellular communication, deteriorated autophagy.

## What do we not know?

What does ageing cause at the molecular level? Why can it be repaired in young organisms but not in old ones?

Clinical trials of senolytics might move toward studies in presymptomatic individuals to delay or prevent age-related conditions.

The remaining gaps in senescence research are the study of the function of senescent cells in other neurological disorders, including traumatic brain injury, spinal cord injury, chronic pain, epilepsy, etc.; the translation of potentials of senolytics in neurological disorders; the study of the dynamics of senescent cell accumulation.

But what can senolytics do in the future?

## Inspiring Examples

Unity Biotechnology was one of the darlings of the nascent anti-aging biotech sector. It listed big-name investors, such as Jeff Bezos and Peter Thiel, an impressive lineup of academic founders and a market valuation that once reached \$700 million. The company was, in effect, the industry's standard-bearer for the therapeutic idea of destroying senescent cells to blunt the ravages of aging.

### **References**

[https://www.who.int/health-topics/ageing#tab=tab\\_1](https://www.who.int/health-topics/ageing#tab=tab_1)

<https://www.age.mpg.de/how-do-we-age>

<https://www.nature.com/articles/s41587-020-00750-1>

<https://www.herl.pitt.edu/symposia/metabolic-pathways/presentations/MP-Zhu.pdf>

Nov. 2023



# STEEP FORCES - MOST IMPACTFUL ONES

## SOCIAL

**AGEING**

DEMOGRAPHIC CHANGES

**MENTAL HEALTH**

LIFESTYLES

DEEPENING DISPARITIES

NON-COMMUNICABLE DISEASES

BEYOND GENDER

MIGRATIONS

WORK FROM EVERYWHERE

DO IT YOURSELF

## TECHNOLOGICAL

**MED(AI)CINE**

AUTONOMOUS SYSTEMS

HYPER-CONNECTED

HUMAN ENHANCEMENT

AVATARS

EXTENDED REALITY

ROBOTICS

DIGITAL TWIN

CRYONICS

GENETIC CONTROL

## ENVIRONMENTAL

PANDEMICS

**ANTIMICROBIAL RESISTANCE**

**GLOBAL CLIMATE CHANGES**

EXTREME EVENTS

**ENVIRONMENTAL DEGRADATION**

PERMAFROST MELTING

POLLUTION

FOOD WASTE

CIRCULAR ECONOMY

BIODIVERSITY LOSS

## ECONOMIC

PRIVATISATION

MORE PREVENTION, LESS CURE

**TECH GIANTS' Pervasiveness**

NEW SPACES, NEW RELATIONS

(UN)PREDICTABLE INSTABILITY

INSURANCE MARKET PLAYERS

**DATA EXPLOITATION**

E-COMMERCE

COST OF LIVING INCREASE

LACK OF SKILLED WORKERS

## POLITICAL

SECURITY

COLLAPSE OF DEMOCRACY

**WELFARE**

(TRANS)NATIONAL IDENTITIES

INFORMATION & CONNECTION

**GEOPOLITICAL COMPETITION**

NUCLEAR PATHS

GLOBAL COMMONS

THE RISE OF ETHICAL QUESTIONS

STATES LIKE SILOS

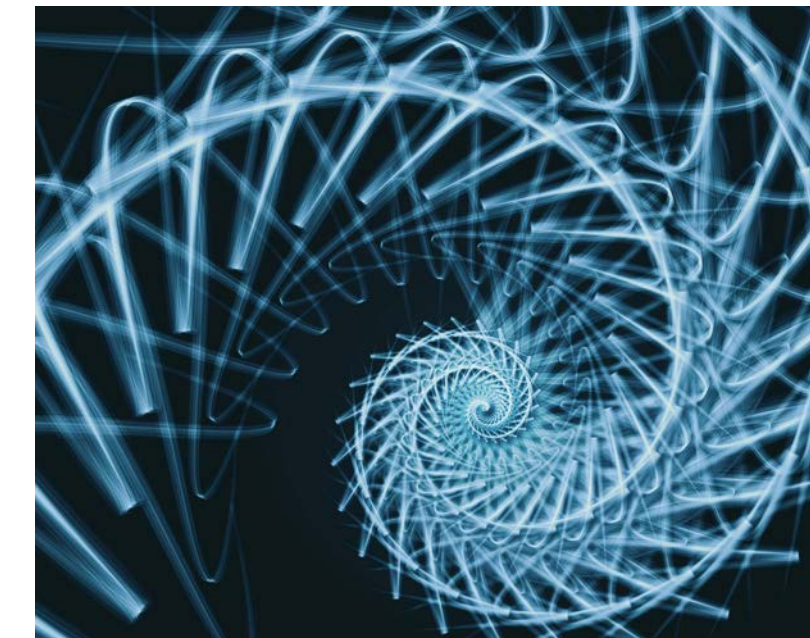


# SIGNALS OF CHANGE

- ◇ A small or local innovation with the potential to scale in size, impact, and geographic distribution
- ◇ Focus attention at the margins of society rather than the core
- ◇ Concrete observations about how the world is changing today



**THOUSANDS  
OF PEOPLE  
SIGNED UP TO  
HAVE CHIP  
IMPLANTED  
IN THEIR  
BRAIN BY  
NEURALINK**



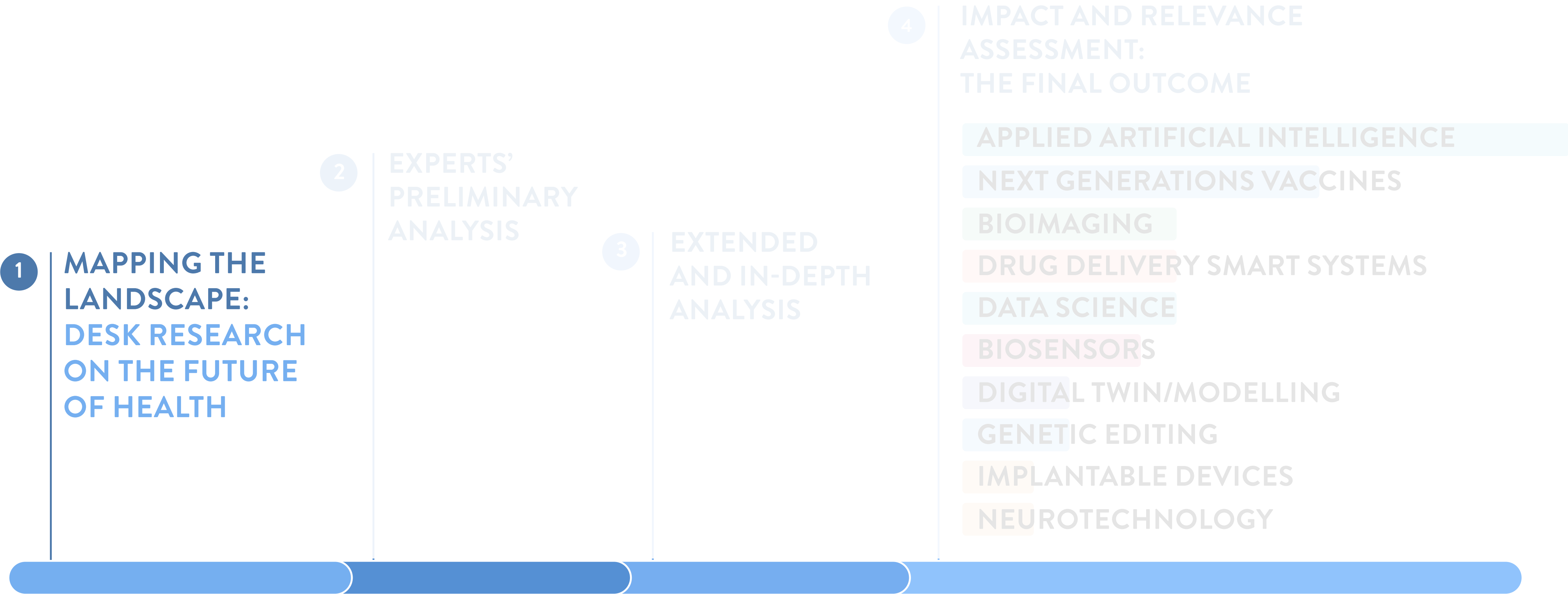
**TYPING  
“I HAVE  
ANXIETY”  
INTO CHATGPT  
HELPS YOU  
IMMEDIATELY:  
THIS HAPPENS  
IN TAIWAN**



**NEW SMART  
TOILET TECH  
TRACKS YOUR  
HEALTH STATS**



# SELECTED LONG-TERM IMPACT TECHNOLOGIES



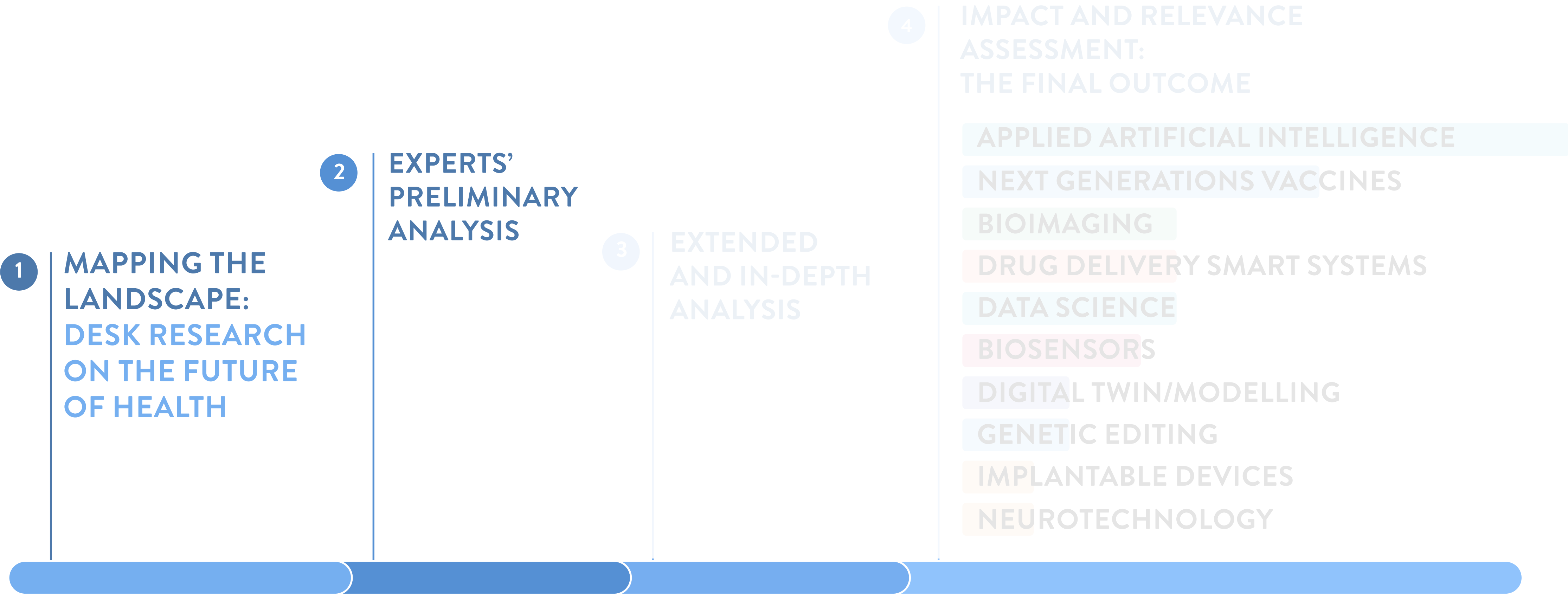


TECHNOLOGY FORESIGHT @ POLIMI

<p><b>STEM CELL TECHNOLOGY</b></p> <p>Replacement or regeneration of muscle, organ, eyes, ears, bone, teeth and, liver, heart, and neural tissues, such as transplantation of neural cells to treat blindness. It is part of regenerative medicine.</p> <p>give new cells in laboratory correct parts of organ research status of genetic defects in cells</p> <p>research how disease occurs test new drugs for safety and effectiveness test new drugs for safety and effectiveness</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>TRIBOELECTRIC NANOGENERATOR</b></p> <p>The human body and internal organ motions can serve as an excellent energy source for Triboelectric Nanogenerator (TENG)-based self-powered healthcare applications. (e.g. drug delivery, neural prostheses, cell modulation, circulatory system, microbial disinfection, gene transfection, hair regeneration, biodegradable electronics).</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>THERANOSTIC</b></p> <p>Theranostics is a combination of the term therapeutics and diagnostics. Theranostics is used to describe the combination of using one radioactive drug to identify (diagnose) and a second radioactive drug to deliver therapy by treat the main tumor and any metastatic tumors.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>ULTRASOUNDS</b></p> <p>Transcranial Ultrasound Stimulation (TUS) The targeted use of ultrasound technology can bring significant changes in brain functions that could pave the way towards treatment of conditions such as depression, addiction, or anxiety, a new study suggest.</p> <p>Emerging Ultrasound Bioelectronics (ULBE) ULBEs with wireless, implantable, or highly integrated forms enable continuous health monitoring and on-demand medical therapy at the point of care, far superior to traditional ultrasound medical procedures, and are serving as the technical base for the state of art personalized medicine.</p> <p>Ultrasound Modulated Fluorescence (UMF) / Ultrasound Switchable Fluorescence (USF) As an emerging technique, UMF or USF combining has three promising features to produce deep-tissue and high-resolution fluorescence imaging for biomedical research and health diagnosis.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>WEARABLE 2.0</b></p> <p>Wearable computing elements are becoming widespread however, these electronic wearable' modulation and bandwidths are limited by digital technology. The new frontier of wearable devices is deeply entangled with biological materials and processes. A new type of wearable device can fabricate organic molecules on-demand for the user using a "cell-free" synthetic biology system.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>WEB 4.0 TECHNOLOGIES</b></p> <p>WEB 4.0 is represented by technologies such as semantic web, AI, enhanced web merger of poles, 3D web (transformation of the web in three-dimensional environments following on from "Second Life") and web as a database. Web 4.0 is the set of web technologies such as augmented reality and big data. Soon, each person will have a digital alter ego and will talk more and more with new interfaces, the intelligent machines and brain-computer interfaces.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>XENOTRANSPLANTATION</b></p> <p>Transplantation of living cells, tissues or organs from one species to another.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>X-RAYS</b></p> <p>X-Rays are a form of electromagnetic radiation, similar to visible light. Unlike light, however, x-rays have higher energy and can pass through most objects, including the body. Medical x-rays are used to generate images of tissues and structures inside the body. If x-rays traveling through the body also pass through an X-ray detector on the other side of the patient, an image will be formed that represents the "shadow" formed by the objects inside of the body.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>
<p><b>SMART PILLS OR PILL MONITORS</b></p> <p>The term "smart pill" refers to miniature electronic devices that are created and designed in the field of pharmaceutical capsules but perform highly advanced functions such as sensing, imaging, and drug delivery. They may include biosensors or image, pH, or chemical sensors. Once they are swallowed, they travel along the gastrointestinal tract to capture information that is otherwise difficult to obtain and then are easily eliminated from the system. Their classification as ingestible sensors makes them distinct from implantable or wearable sensors.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>SIO-MEMBRANE/ELECTROSPUN</b></p> <p>Electrospun nanofiber membranes are regarded as good catalyst-supporting materials owing to their advantages such as large specific surface area and pore volume, controllable pore size distribution, and negligible mass transfer resistance inside the membrane. There have been many reports on nanofibers carriers for catalyst nanoparticles or enzymes.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>ROBOTICS</b></p> <p>Robotics is a branch of engineering and computer science that involves the conception, design, manufacture, and operation of robots. The objective of the robotics field is to create intelligent machines that can assist humans in a variety of ways. Robotics can take on several forms. A robot might resemble a human or be in the form of a robotic application, such as robotic process automation, which simulates how humans engage with software to perform repetitive, rules-based tasks.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>PROSTHETICS</b></p> <p>An artificial body part, such as an arm, foot or hand, and/or a prosthetic device, such as a hearing aid, exoskeletons for spinal cord injuries, prosthetic fingers and arms, knee joint replacements, whole range hearing aids, bionic eyes, and electronic affliction).</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>PAIN BLOCKER</b></p> <p>One in five adults lives with chronic pain. Pain signals travel along nerves. Now 1.7 trillion channels. No one knows where channel blockers are in development, with three already in clinical trials. The potential to decrease pain more radically, without the side effects of opioids, could reduce a huge portion of the population from debilitating.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>3D PRINTING</b></p> <p>3D bioprinting is a technology where bioinks, mixed with living cells, are printed in 3D to construct natural tissues like three-dimensional structures. Currently, this technology can be used in various research areas such as tissue engineering and new drug development.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>OMICS TECHNOLOGY</b></p> <p>Single-cell omics technologies are used to better understand and interpret diseases, intervene earlier and more effectively in prevention, diagnosis and treatment. It's a field about the relations and interactions between the human genome, nutrition and health. There is substantial diversity in the types of 'omics, but their common objective is to comprehensively characterize structural or functional features of a class of biological molecules in a cell, tissue, or organism.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>OLIGONUCLEOTIDE THERAPEUTICS</b></p> <p>Oligonucleotides are a class of single- or double-stranded small synthetic nucleic acid polymers. They can be used to modulate gene expression through a range of processes, including RNAi, target degradation by RNase H-mediated cleavage, splicing modulation, non-coding RNA inhibition, gene activation, and programmed gene editing. As such, these molecules have potential therapeutic applications for myriad indications, with several oligonucleotide drugs recently gaining approval.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>
<p><b>NEUROTECHNOLOGY</b></p> <p>Neurotechnology seeks to understand, enhance, and repair the human brain. A neurotechnology is a technology that continuously controls and stimulates neural impulses. While a portion of neurotechnology is used for research, to study neural lines or sleep patterns, increasingly it is being used to influence the brain or brain system for therapeutic or rehabilitative purposes. Conditions such as Parkinson's, Alzheimer's, major depression, and brain injury could all find relief through neurotechnology. The devices used in alleviating these conditions are of infinite value to healthcare as populations become increasingly older, and life expectancy increases, the demand for effective treatment for neurological disorders will climb.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>NANOTECHNOLOGIES</b></p> <p>Nanotechnology deals with the engineering of systems at the atomic and molecular level. It combines components of molecular chemistry and physics with engineering to gain an advantage over the unique changes to the properties of materials that occur at nanoscale. A major challenge facing the healthcare industry is the human body's inability to sometimes absorb entire doses of drugs. This is where nanotechnology comes into the picture. Nanotechnology can be used to transport the drug to specific cells in the body, which not only ensures a more precise treatment but also reduces the chances of failure or rejection.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>NANOMEDICINE</b></p> <p>Branch of medicine that seeks to apply nanotechnology to the prevention of disease and to imaging, diagnosis, monitoring, treatment, repair, and regeneration of biological systems. Although nanomedicine remains in its early stages, several nanomedical applications have been developed. Research that has focused on the development of biosensors to aid in diagnostics and vehicles for administering vaccines, medications, and genetic therapy, including the development of nanocarriers to aid in cancer treatment.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>NANOMATERIALS</b></p> <p>Nanomaterials can circulate through the body by moving in and out of blood vessels, enter cells and interact with biomolecules both on the cell surface and inside cells in numerous areas of the human body. Thus, nanomaterials have the potential to detect disease, deliver treatments and allow prevention in new ways. The main therapeutic benefits of using nanomaterials are as follows: solubility (for otherwise insoluble drugs), barriers for hydrophobic entities, multifunctional capability, active and passive targeting, (spatial scale exclusion) and reduced toxicity.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>MODELING</b></p> <p>Modeling is the generation of a physical, conceptual, or mathematical representation of a real phenomenon that is difficult to observe directly. Scientific models are used to explain and predict the behavior of real objects or systems and are used in a variety of scientific disciplines. Some models, such as the three-dimensional double-helix model of DNA, are used primarily to visualize an object or system, often being created from experimental data. Other models are intended to describe an abstract or hypothetical behavior or phenomenon.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>MICROPHYSIOLOGICAL SYSTEMS</b></p> <p>A microphysiological system (MPS) is an interconnected set of two- or three-dimensional cellular constructs that are frequently referred to as organ-on-chips or in vitro organ constructs. The constructs are made with commercialized cell lines, primary cells from animals or humans, or, more recently, organ-specific cells derived from stem cells, human embryonic stem cells, and induced pluripotent stem cells.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>MICRO-ELECTROMECHANICAL SYSTEMS</b></p> <p>Micro-Electromechanical Systems (MEMS) is the technology of microscopic devices incorporating both electronic and moving parts. They usually consist of a central unit that processes data (an integrated circuit chip such as microprocessor) and several components that interact with the surroundings (such as microsensor).</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>METaverse</b></p> <p>A metaverse can be any 3D virtual space powered by technologies – including virtual reality, augmented reality (AR), artificial intelligence (AI), the Internet of Things (IoT), and blockchain – that enable people to interact with each other (and in some cases, with non-human entities).</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>
<p><b>GENETIC TESTING</b></p> <p>Genetic testing can provide a diagnosis for a genetic condition, for example, the risk of developing cancer. There are many kinds of genetic tests, which are done using blood or spit sample and results are usually ready in a few weeks.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>GENOME SEQUENCING</b></p> <p>The process of determining the entirety, or nearly the entirety, of the DNA sequence of an organism's genome at a single time.</p> <p><b>Future applications?</b></p> <p>Address: <a href="#">https://www.researchgate.net/publication/317920246</a></p>	<p><b>HADRONTHERAPY</b></p> <p>Radiation therapy is the medical use of ionizing radiation to treat cancer. In conventional radiation therapy, beams of X-rays (high energy photons) are produced by accelerated electrons and then directed to the patient to destroy tumor cells. The next step in radiation therapy is the use of carbon and other ions. These have some clear advantages over x-rays in providing both a high control of very aggressive tumors and a lower acute side effect toxicity. In Europe, the interest in hadrontherapy has been growing rapidly and</p>					

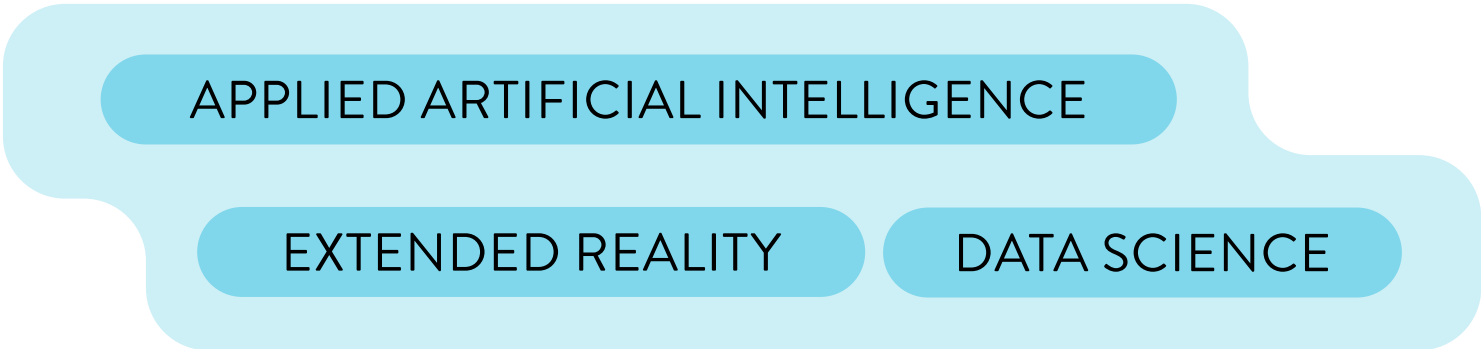


# SELECTED LONG-TERM IMPACT TECHNOLOGIES

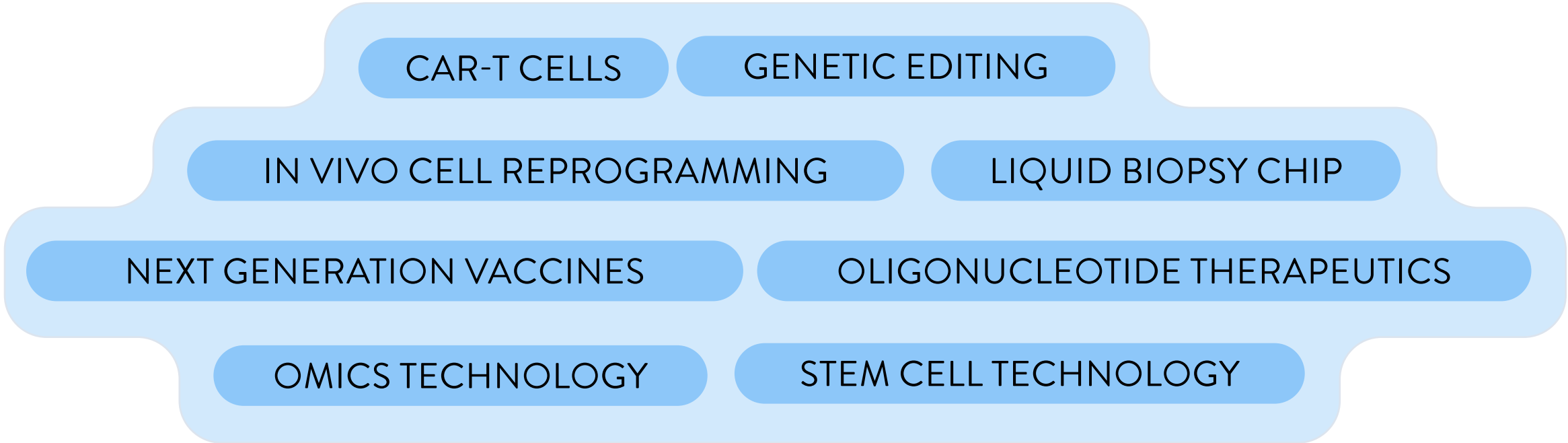




# ... TO 28 TECHNOLOGIES



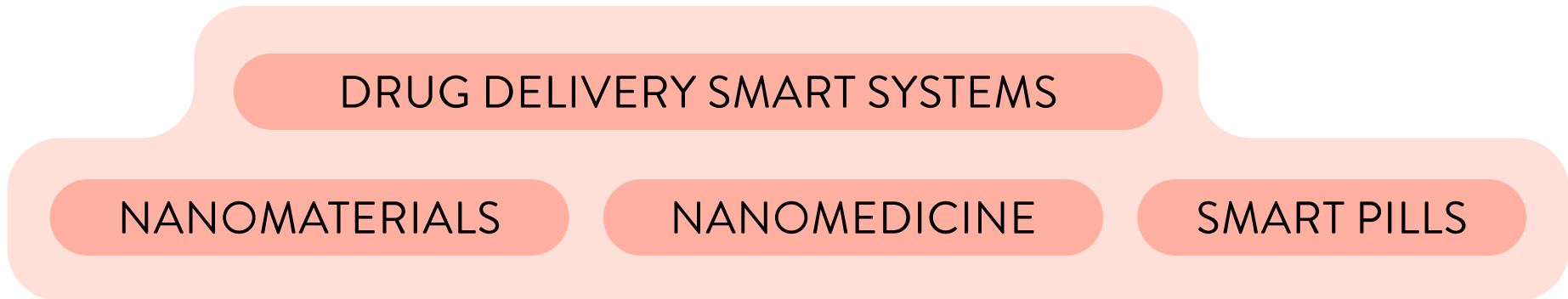
DATA, XR & AI



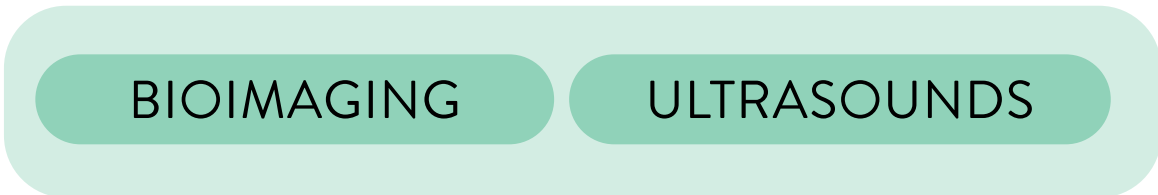
GENETICS



DIGITAL



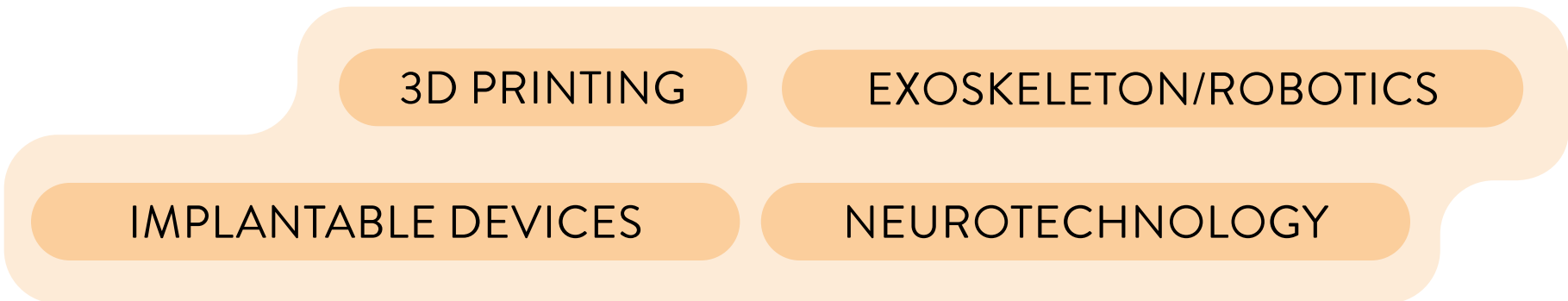
NANO



IMAGING



WEARABLE & SENSOR



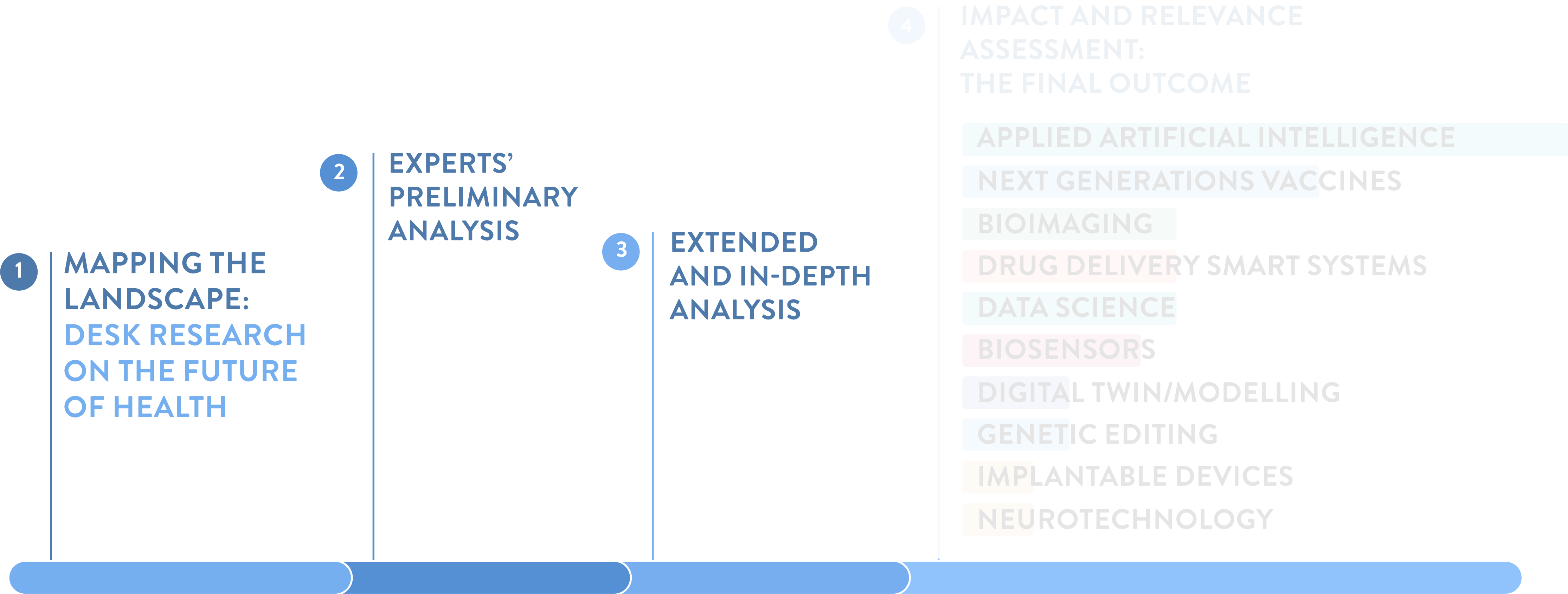
DEVICES



OTHERS

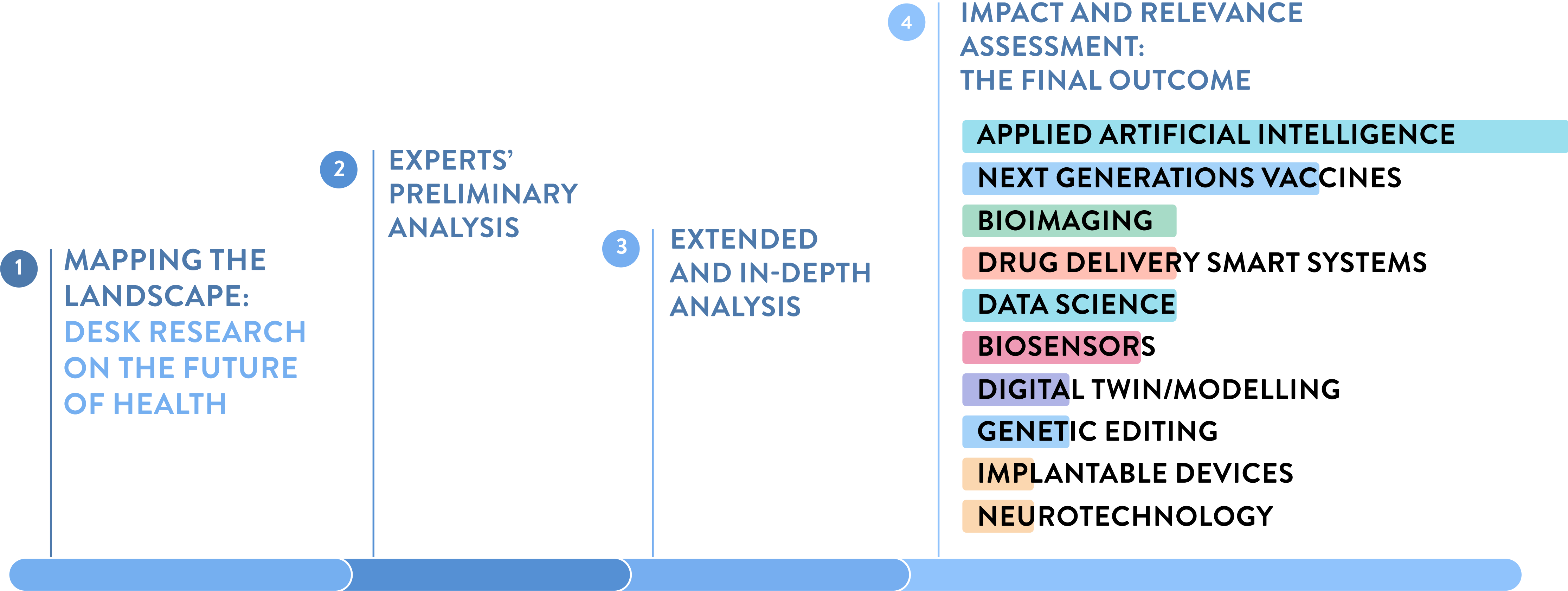


# SELECTED LONG-TERM IMPACT TECHNOLOGIES

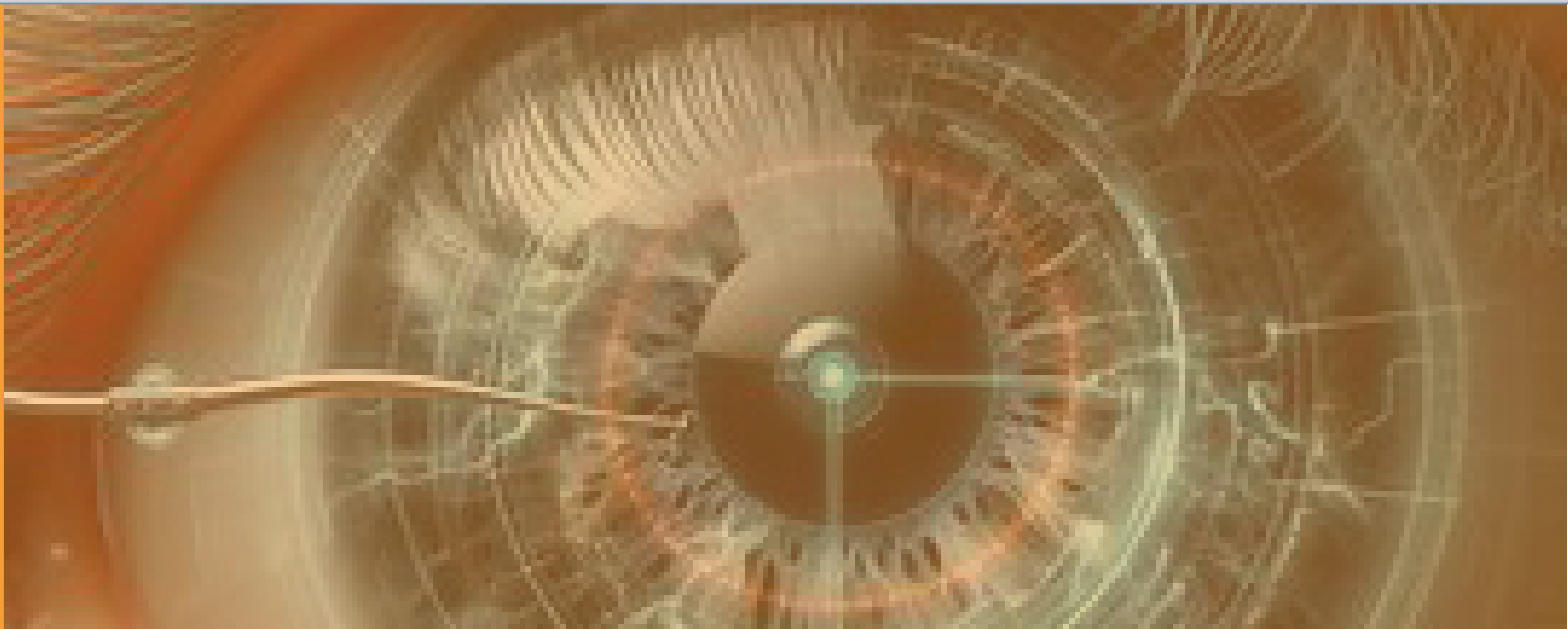




# SELECTED LONG-TERM IMPACT TECHNOLOGIES







## IMPLANTABLE DEVICES

An implantable device is an active medical device intended to be fully or partially inserted into the human body for diagnostic or therapeutic purposes, with the intention of remaining in place. Due to their direct and long-term contact with the body, implantable devices are subject to rigorous standards and requirements to ensure the health and safety of patients.

Not only implantable, but also wearable technologies will play a central role. The ubiquity of wearable computing elements is on the rise, albeit hindered by inherent limitations in resolution and bandwidth imposed by current digital technology paradigms. This evolution now intersects with biological frameworks and processes, paving the way for a transformative era in healthcare.

### EXAMPLES OF POTENTIAL FIELDS OF APPLICATION

- Remote patient monitoring
- Glucose monitoring
- Heart rate monitoring
- Connected contact lenses
- Parkinson's disease monitoring
- Depression and mood monitoring
- Ingestible sensors connected inhalers

### PHASES

- PREDICTION
- PREVENTION
- DIAGNOSIS
- TREATMENT
- REHABILITATION

### OPPORTUNITIES

- Continuous monitoring of vital parameters
- Citizen-centred care and 6P medicine (Preventive, Predictive, Participatory, Personalized, Psychosocial, Platforms)
- Development of new families of wearable sensors (smart rings, smart glasses)

### REQUIREMENTS

- Massification of wearable and implantable technologies
- Availability and affordability
- Miniaturized batteries
- Data analysis
- Data management models
- Organisation of information campaigns

### RISKS

- Psychological stress, agitation and/or hypochondria due to control and technological dependence on continuous measurement
- Over-diagnosis and obsession
- Invasiveness of drug delivery for implantable devices
- Possibility of self-determination and the choice to refuse continuous control
- Medicalisation of existence
- Lack of common platforms for data collection and analysis

### IMPACTS

- Quasi-normal lifestyle for individuals requiring medications and continuous monitoring





## DIGITAL TWIN/MODELLING

A Digital Twin is a set of virtual information constructs that mimics the structure, context, and behaviour of a natural, engineered, or social system. It is dynamically updated with data from its physical twin, has a predictive capability, and informs decisions that realise value. Health digital twins (HDTs) are virtual representations of patients, derived from diverse patient data sources, population data, and real-time updates concerning patient and environmental variables. Through meticulous application, HDTs can simulate random deviations in the digital twin to elucidate anticipated behaviours of the physical counterpart, thereby offering revolutionary implications in precision medicine, clinical trial methodologies, and public health initiatives.

### EXAMPLES OF POTENTIAL FIELDS OF APPLICATION

Access to data-driven insights regarding operational strategies, capacity, staffing and care models

Monitoring

Development of a unique model for each patient

### PHASES

PREDICTION

PREVENTION

DIAGNOSIS

TREATMENT

REHABILITATION

### OPPORTUNITIES

- Prediction of disease progression
- Identification of high-risk individuals
- Recommendation of preventive measures
- Monitoring without the implications of presence checks
- Relief for the healthcare system
- Personalised medicine

### REQUIREMENTS

- Creation of predictive models
- Data collection and data availability
- Interoperability of data
- Development of decision models (with probabilistic formulation)

### RISKS

- Lack of systems allowing for interoperability of data
- Privacy of data and non-medical uses
- Overconfidence in the adoption of the tool within the clinical decision-making process

### IMPACTS

- Reshaping industries to increase efficiency and identify issues
- Treatment of patients as virtualised standalone assets
- Improvement in treatment and diagnostics within hospitals and for individual patients



# IMAGING OUR FUTURE ... ENVISIONING TOGETHER

- ◇ alternative visions and futures' analysis
- ◇ personal health paradigm
- ◇ opportunities and challenges' discourse
- ◇ insights: in-depth analysis into possible future developments





# EMERGENT ASPECTS: INSIGHTS

AUTO-MONITORING & SELF-TRACKING  
FOR AN ACTIVE POPULATION ENGAGEMENT

ETHICS, PRIVACY, AND SECURITY

MORE PREVENTION, LESS CURE

MODELLING AND DATA

(RE)NEW(ED) RELATIONSHIPS: CAREGIVERS, FAMILY,  
AND NEW COLLABORATIVE COMMUNITIES

MENTAL HEALTH AND WELL-BEING

NEW DISEASES AND NEW FORMS OF DISCRIMINATION

HEALTHCARE SUSTAINABILITY

A REMOTE ONLINE LIFE

EMPATHY AND THE NARRATIVE DIMENSION OF THE PATIENT

PERSONALISED MEDICINE

WIDESPREAD EDUCATION: HEALTH PROFESSIONALS'

EDUCATION, AND HEALTHCARE NETWORKS



# AUTO-MONITORING AND SELF-TRACKING FOR AN ACTIVE POPULATION ENGAGEMENT

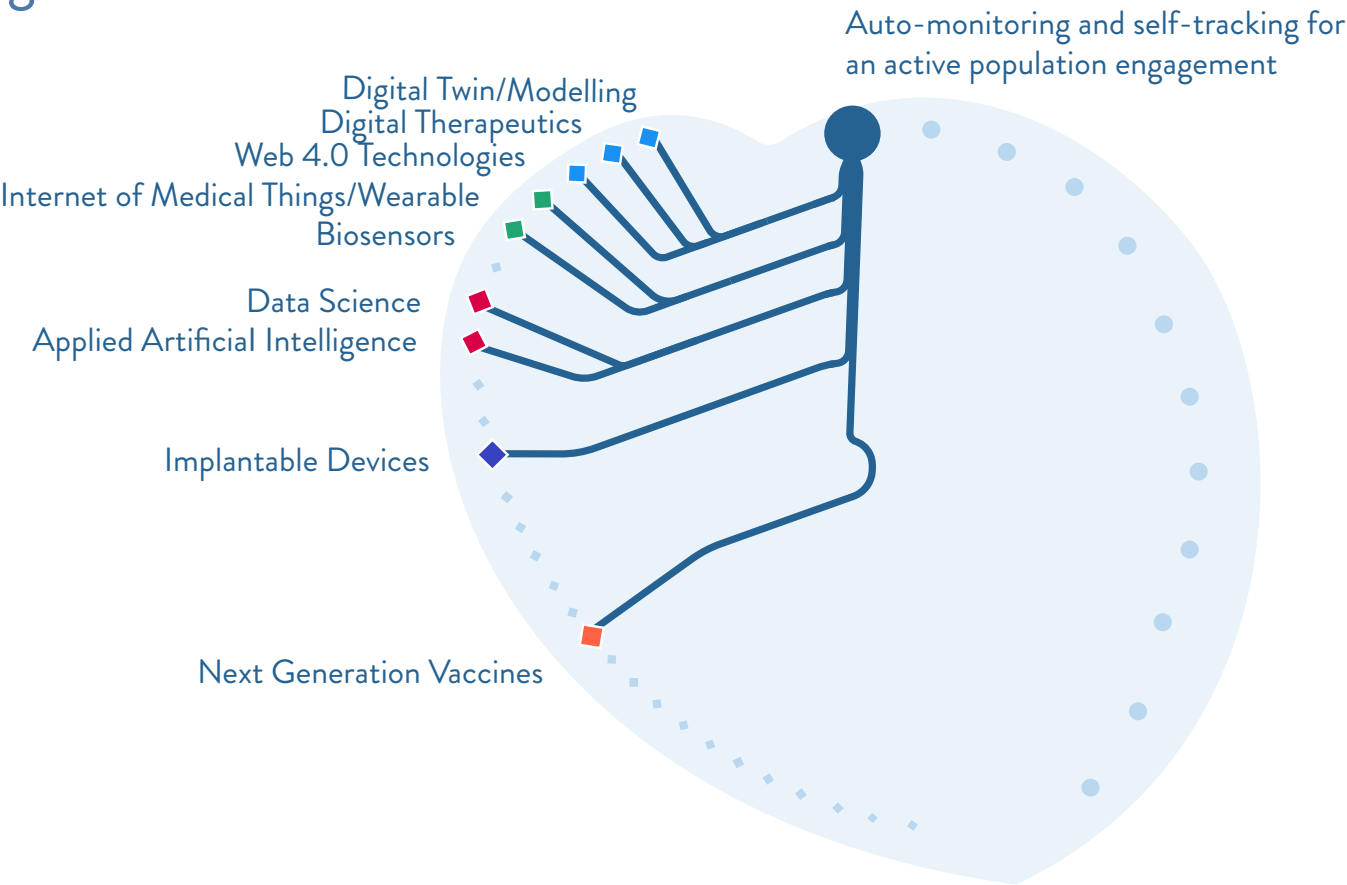
The **active involvement of patients**, families, and the community at large is essential to advance predictive models. The overall goal is to promote autonomy and self-sufficiency by empowering people to effectively manage their own care.

To this end, harnessing **collective intelligence** through information crowdsourcing is crucial. It is necessary to promote awareness through widespread dissemination and create care networks that incorporate voluntary resources as additional support to the healthcare system.

Self-monitoring could support the maintenance of physical and mental health through constant monitoring of vital parameters. Collectively, continuous monitoring could benefit healthcare by providing data for predictive and preventive modelling.

At the same time, the implications of **self-monitoring** are manifold. Sociality could change and psychological risks increase in a context where existence is pervaded by progressive medicalisation.

## Technologies



## STEEP Forces





# MODELLING AND DATA

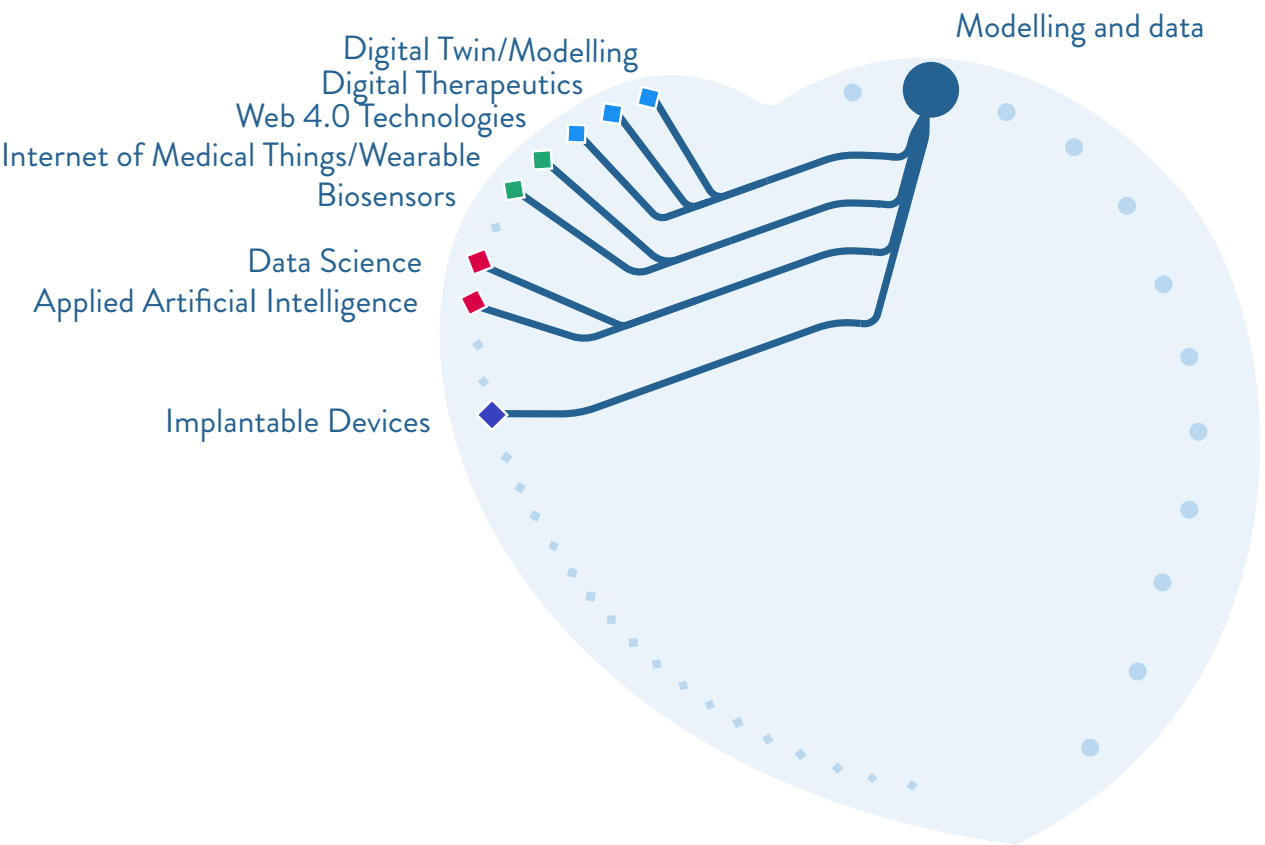
The availability of data and the ability to analyse them are the new gold rush to predict and prevent diseases. It is necessary to develop simulation systems and technologies to implement clinical research based on **real world data** and define new criteria for **predictive modeling**.

Advanced predictive models and extensive data availability can enhance health outcomes. However, due to the intimate nature of this data, **data protection** and **new privacy paradigms** are essential to prevent unauthorised use.

An information system for citizens must be developed so that they are aware of the use of monitoring systems.

Situations where individual narratives are depersonalised through the use of models and data, as well as their inappropriate use for non-medical purposes, raise significant questions for the future.

## Technologies



## STEEP Forces





# TRANSFORMATIVE PERSONAL HEALTH TECHNOLOGIES IN 2040

STEEP Forces, Technologies and Insights

## STEEP FORCES

### Social

- Ageing
- Non-communicable diseases
- Mental health
- Lifestyles
- Deepening disparities
- Demographic changes
- Beyond gender
- Migrations
- Work from everywhere
- Do it yourself

### Technological

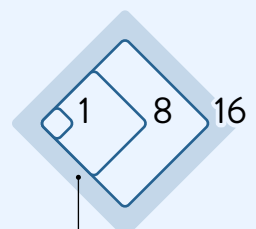
- Med(AI)cine
- Autonomous systems
- Hyper-connected
- Human enhancement
- Extended reality
- Robotics
- Digital twin
- Cryonics
- Genetic control
- Avatars

## HOW TO READ IT

### Technologies

#### Size

Amount of votes



#### Highlight

Most relevant technologies emerged from the participants' survey results

#### Colour

Category

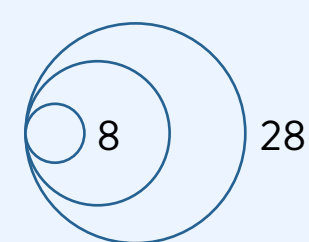
- Digital
- Wearable & Sensors
- Data, XR & AI
- Others
- Devices
- Imaging
- Genetics
- Nano

### Insights

Insights have technologies connected to them

#### Size

Amount of connected technologies



### STEEP Forces

Bar length shows survey results.

## TECHNOLOGIES

### Digital Twin/Modelling

Digital Therapeutics

Web 4.0 Technologies

Internet of Medical Things/Wearable

### Biosensors

Extended Reality

### Data Science

### Applied Artificial Intelligence

Fluid Interfaces

Microphysiological Systems

### Implantable Devices

### Neurotechnology

Exoskeleton/Robotics

3D Printing

### Bioimaging

Ultrasounds

### Next Generation Vaccines

CAR-T Cells

### Genetic Editing

In Vivo Cell Reprogramming

Oligonucleotide Therapeutics

Omics Technology

Liquid Biopsy Chip

Stem Cell Technology

Nanomaterials

### Drug Delivery Smart Systems

Smart Pills

## INSIGHTS

Auto-monitoring and self-tracking for an active population engagement

Modelling and data

More prevention, less cure

Widespread education: health professionals' education and healthcare networks

A remote online life

(Re)new(ed) relationships: caregivers, family, and new collaborative communities

Mental health and well-being

Healthcare sustainability

Empathy and the narrative dimension of the patient

Ethics, privacy, and security

New diseases and new forms of discrimination

Personalised medicine

## Environmental

- Pandemics
- Antimicrobial resistance
- Global climate changes
- Extreme events
- Environmental degradation
- Permafrost melting
- Pollution
- Food waste
- Circular economy
- Biodiversity loss

## Economic

- Privatisation
- E-commerce
- Cost of living increase
- More prevention, less cure
- Insurance market players
- (Un)predictable instability
- New spaces, new relations
- Tech giants' pervasiveness
- Data exploitation
- Lack of skilled workers

## Political

- Security
- Collapse of democracy
- Welfare
- (Trans)national identities
- Information and connection
- Geopolitical competition
- Nuclear paths
- Global commons
- The rise of ethical questions
- States like silos



POLITECNICO  
MILANO 1863

TECHNOLOGY FORESIGHT



# TECHNOLOGIES' ANALYSIS

- ◇ **opportunities** provided by technologies with respect to the application contexts
- ◇ enabling factors, **requirements** necessary for the technology to make an impact
- ◇ evaluating potential **risks** related to the use of technology (often technological dual use)
- ◇ expected **impacts** the technology can actually have in transforming the personal health scenario



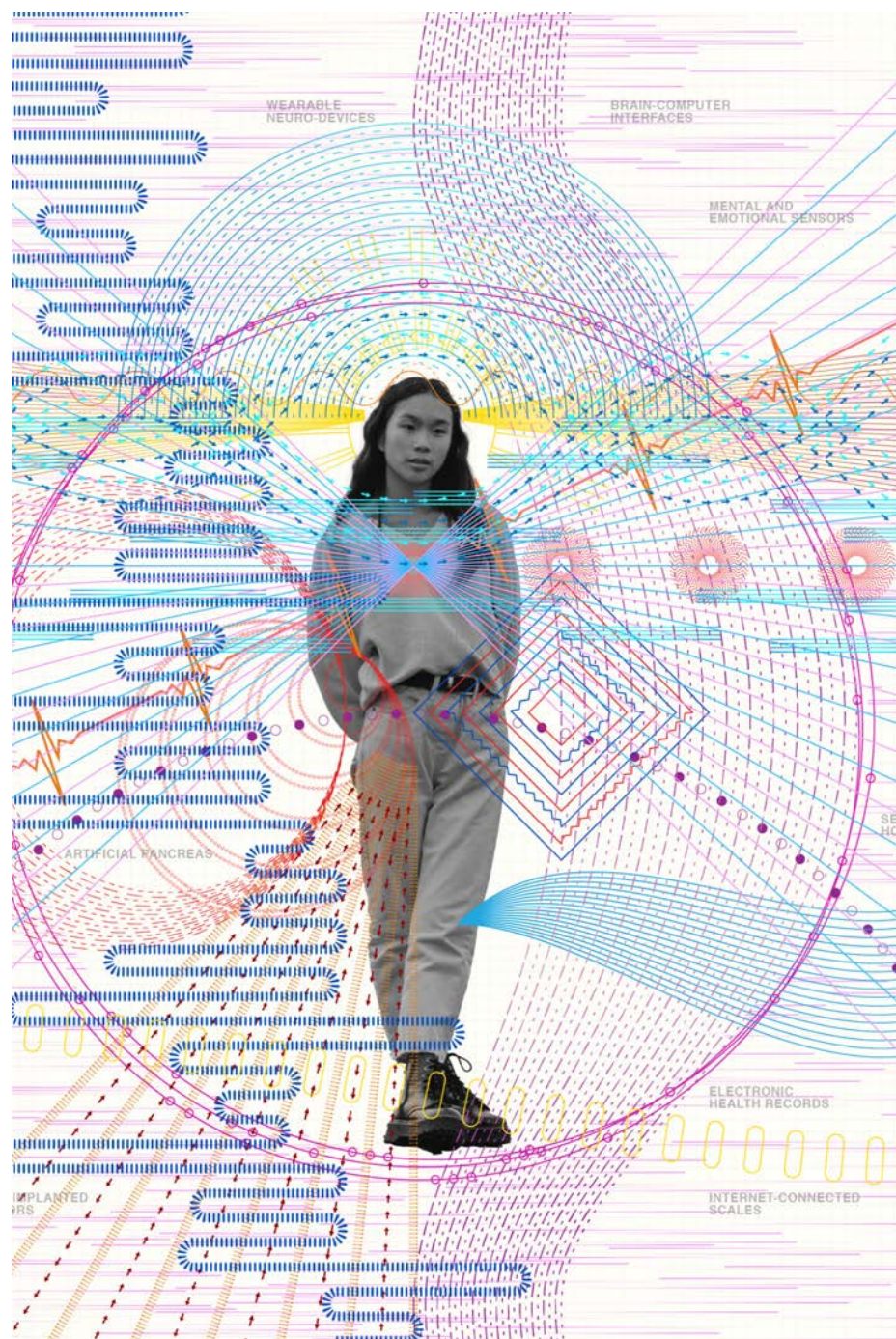
image credits: <https://t.ly/3PGk3>



# TAKE-HOME MESSAGES

## DIGITAL HEALTH

humans as data in  
hyper-connected  
societies



## PROACTIVE HEALTHCARE

from cure to prevention  
through prediction



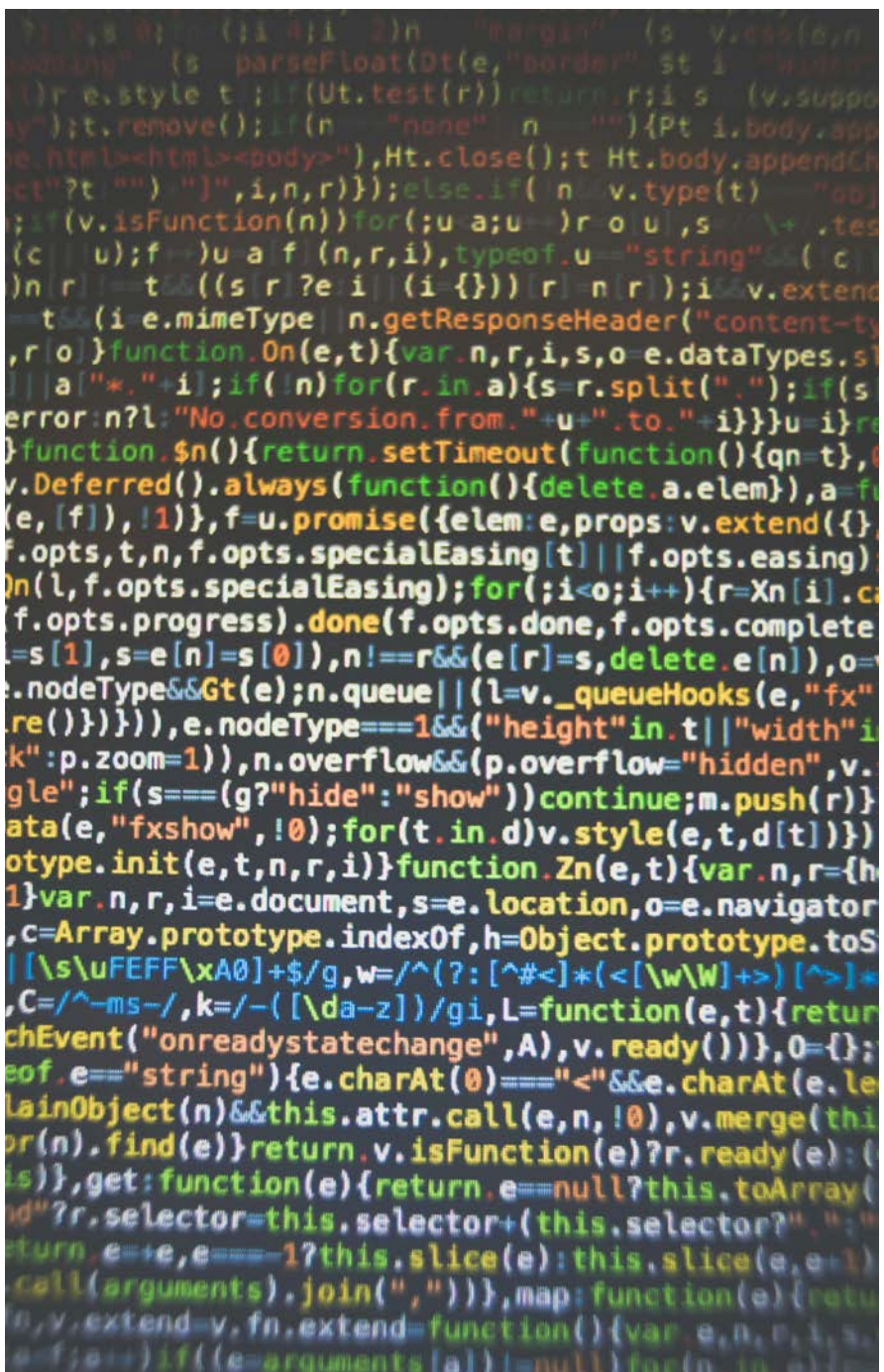
## MYDICINE

increasingly  
tailored medicine



## SUSTAINABILITY & EQUITY

challenges to reduce  
the gaps





# NEXT STEPS

- ◇ How will new technologies change the structures of the **healthcare system**?
- ◇ What new relationships will be established with the advent of new technologies at the **ecosystem level**?



image credits: <https://t.ly/MH7QN>



# PARTICIPANTS / THANKS TO

◆ **Andrea Aliverti**

◆ Giuseppe Andreoni

◆ Guido Baroni

◆ Giuseppe Baselli

◆ Andrea Bassi

◆ Anna Maria Bianchi

◆ Gabriele Candiani

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◆ Bianca Colosimo

◆ Maria Laura Costantino

◆ Gabriele Dubini

◆ Giancarlo Ferrigno

◆ Carlo Fiorini

◆ Pierangelo Metrangolo

◆ **Franco Molteni**

◆ Alessandra Pedrocchi

◆ Dario Polli

◆ Maurizio Quadrio

◆ Manuela Raimondi

◆ Marco Rasponi

◆ Alberto Redaelli

◆ Laura Sangalli

◆ Marco Tarabini

◆ Paola Taroni

◆ **Luca Vago**

◆ Paolo Zunino



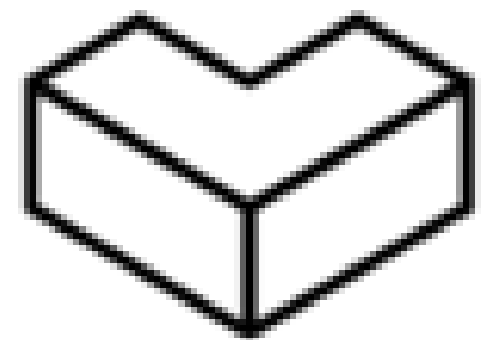
# RESEARCH ASSOCIATES

Ingrid Alloni

Sabrina Carelli

Alberto Speroni

## IN COLLABORATION WITH



**LEADIN'**  
LAB

LEAdership. Design. Innovation.

Claudio Dell'Era  
Stefano Magistretti  
Daniel Trabucchi



