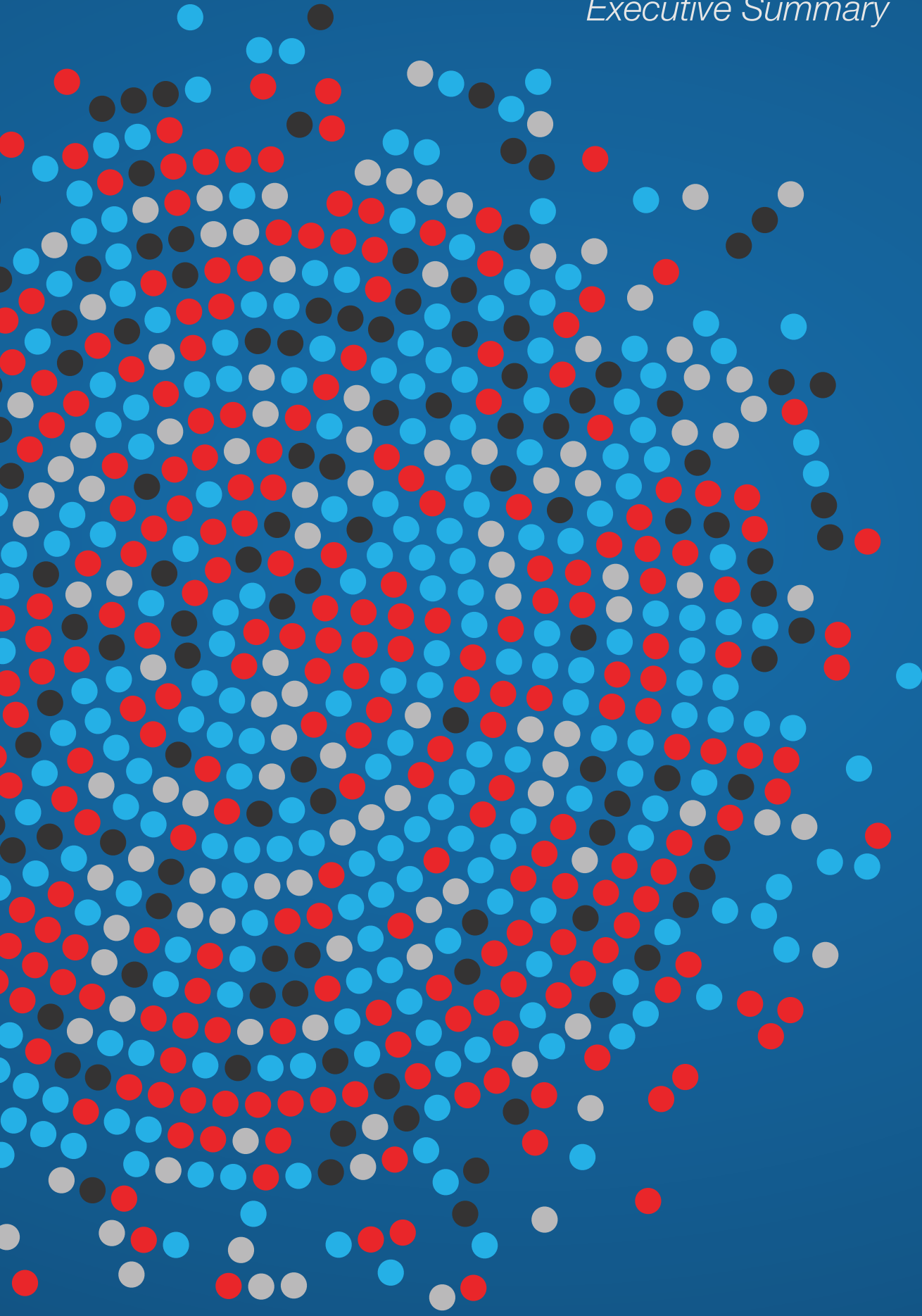




Strategic Research Agenda

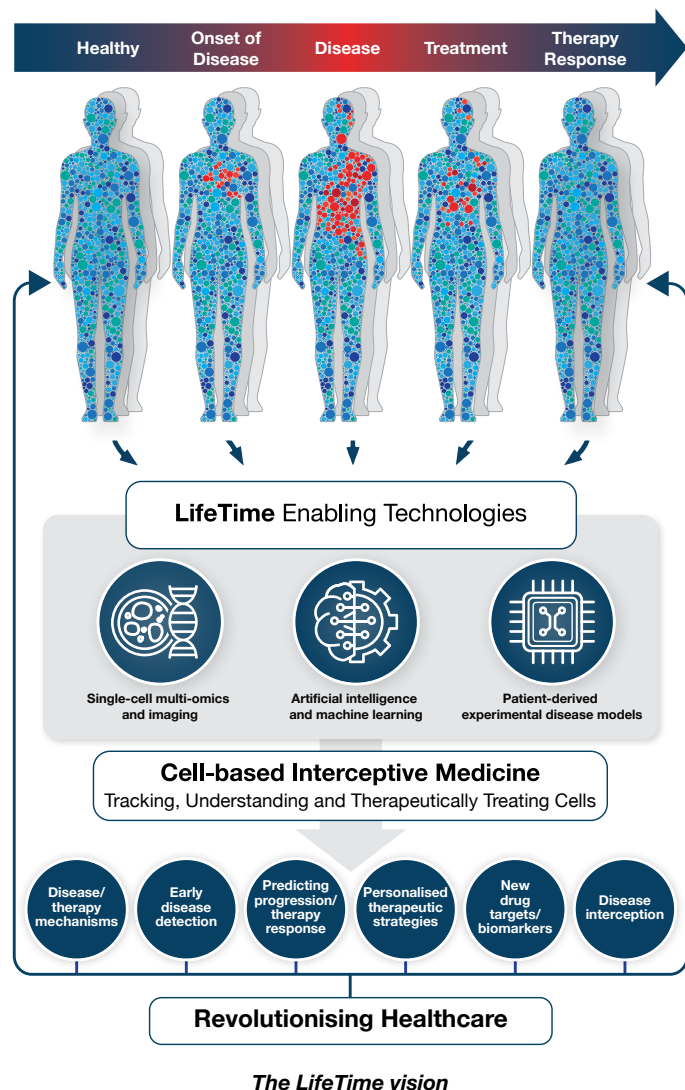
Executive Summary



European citizens are living longer, gaining years, which they should spend with the highest quality of life. To ensure that people remain healthy throughout their lifetime, Europe needs a new approach to medicine. Not only do we have to change the way diseases are detected and treated, we also need to think ahead and prepare for emerging health challenges. Digital and biomedical technologies have the capacity to potentiate other breakthroughs and transform medicine. They can impact every stage of medical care from early disease detection, correct diagnosis, selection of the most effective treatment and protect recovering patients from the threat of therapy resistance and relapse. Their integration promises to provide high-quality healthcare, strengthen Europe's research and health industry, innovation capacity and global leadership.

Creating a new generation of digital health and biomedical technologies will offer solutions for medical and societal challenges. Disruptive research and breakthrough innovation enabled by these technologies will provide the necessary new approaches to prevent suffering from diseases through new modes of detection and diagnosis. By understanding the underlying causes of a disease, the right therapy can be selected for a patient and new drugs and therapies can be developed based on this knowledge. Not only will this lead to healthier lives and ageing for Europe's citizens but also relieve the growing unsustainable burden on its healthcare systems over the next decade.

LifeTime, as a large-scale long-term research initiative proposes to generate the technologies required to drive a new digital age in medicine. Instead of diagnosing diseases once symptoms arise, LifeTime aims to detect them much earlier to increase the opportunities for intercepting disease before irreparable damage occurs and curing patients by treating disease causes instead of their symptoms. Driving this transformative change in medicine requires more knowledge of the molecular basis initiating disease at the level of individual cells, the fundamental building blocks of our bodies. Understanding and predicting the future course of a disease and its response to treatment requires knowledge of the hundreds of thousands of different molecules in a single cell and how these differ between millions of cells in tissues and across many thousands of individuals in a population. Detecting and therapeutically targeting the specific cells that cause diseases is key to intercepting and curing them. Digital health solutions will provide ways to create and unlock the potential of biomedical 'big data' and implement cell-based interceptive medicine in Europe.



LifeTime aims to:

- Understand diseases and therapies at cellular resolution and use this information to intercept diseases by creating and integrating new digital and biomedical technologies**
- Establish approaches that enable the large-scale sharing and use of medical data across national borders to provide personalised health solutions for European citizens**
- Enable long-term European leadership in cell-based interceptive medicine through developing new technologies and driving innovation at the interface of multiple sectors**
- Develop a dialogue with citizens and stakeholders, ensuring an ethically-sound implementation and making citizens active contributors to European research and health strategic decisions**

The LifeTime Strategic Research Agenda (SRA) lays out the priorities for developing and integrating the next generation of digital and biomedical technologies - single-cell multi-omics and imaging, artificial intelligence and machine learning and patient-derived experimental disease models - and their introduction into medical practice in the next decade. It details ten-year roadmaps for co-developing these technologies during multidisciplinary research programmes and applying them in the clinics to address urgent medical challenges. These roadmaps are supported by key programmes covering industry and innovation, ethics, legal, societal issues and education and training to introduce cell-based interceptive medicine.

Developing Technologies for Cell-based Medicine

Sequencing of the human genome launched the vision of precision medicine, whereby the right therapeutic strategy is tailored for an individual at the right time. Until now we have lacked the required approaches to understand how an individual's genetic information influences the molecular status of individual cells and use this knowledge to drive precision medicine. Integrating different breakthrough technologies will make it possible to discover the cellular basis of health and disease at a resolution that has previously been impossible. Creating new single-cell multi-omics and imaging technologies will provide information on the different types of molecules in cells, their position in tissues, interactions with other cells and their origin to quantify their status in health and disease. This will generate the essential 'big' high-quality data to unlock the potential of artificial intelligence in medicine. Machine learning approaches will integrate and extract meaningful information on a patient's health or disease. These computational models will discover molecular mechanisms, predict the future course for a particular patient and the most effective therapeutic options, which will be tested in cell and tissue models derived from patients to ensure that the most effective therapy is provided. Use of this data across Europe will require investment in computational infrastructure for storing, accessing and querying data across national borders. This is a golden opportunity for Europe to drive the establishment of standardised technologies, data formats to ensure interoperability and secure access. In parallel, the process will promote health-data exchange and research on preventative strategies, therapies and outcomes. Currently, the US, China and Europe are investing heavily in precision medicine. However, only the US and China are also investing in large-scale single-cell technology-driven initiatives such as the Human BioMolecular Atlas Program (HuBMAP), Human Tumor Atlas Network (HTAN), 10 Million Single-Cell Transcriptome Project (scT10M) to better understand human biology and disease. Europe needs to step up and build on its precision medicine investments to ensure that it establishes itself as a leader in cell-based interceptive medicine.

Solving Disease Challenges Through Cell-based Interceptive Medicine

Detecting and correctly diagnosing diseases sufficiently early, selecting a therapy to which a patient will respond and developing disease-modifying therapies are current barriers in medicine. To rapidly translate the development of new technologies to benefit patients, LifeTime has identified key medical challenges where single-cell analysis, artificial intelligence and patient-derived cell and tissue models can make the greatest impact for patients. This SRA details current medical challenges and provides five ten-year roadmaps, where investment in research is required at the interface of biology, artificial intelligence, mathematics, engineering and medicine. Multidisciplinary research programmes will create next-generation technologies and apply them to large-scale patient populations to move beyond the currently limited one-size-fits-all approach to medicine. These address the current barriers to effectively treating and curing cancer, neurological and neuropsychiatric diseases, infectious diseases, chronic inflammatory diseases as well as cardiovascular and metabolic diseases. Newly created artificial intelligence-based approaches will alert and guide a physician's decision-making process to select the best therapy strategy for an individual as well as identify new validated drug targets for the pharmaceutical industry. Within a decade, the next-generation biomarkers discovered through biomedical 'big' data driven solutions will enable the implementation of precision medicine based on the early detection and targeting of specific cell populations.

Creating an Interactive Community to Drive European Innovation and Competitiveness

An undertaking as far-reaching as realising cell-based interceptive medicine across Europe cannot be achieved by cutting-edge academic research alone. New cost-effective enabling technologies and instrumentation need to be co-developed, standardised and commercialised to make sure they become widespread in both research and clinical use. Products need to be brought to market readiness, adhere to regulatory guidelines and provide information that can be immediately used by physicians in the clinic. This task is the responsibility of the biotechnology, pharmaceutical and IT sectors, who need to rapidly pick up discoveries from research and translate them into medical solutions. An integrative dynamic ecosystem is necessary to stimulate innovation and facilitate interactions between relevant players. Together with industry, LifeTime proposes five synergistic engagement platforms in this SRA: i) technology adoption and development, ii) strategic partnerships, iii) networking brokerage, iv) entrepreneurship and v) expert advising. They address important bottlenecks that currently hinder cross-sectoral exchange. If implemented, they will drive solution-oriented breakthrough discovery, foster transition from lab to market, stimulate the creation of spin-offs and contribute to new research and innovation policies. A competitive innovation framework for innovative ways of interacting and sharing risk between stakeholders, supporting public/private partnerships, and business creation will generate a highly dynamic and attractive market space for accessing early-stage innovations. The suggested measures will require significant investments such as those introduced by other global leaders. But more than just committing funds, it is necessary that all stakeholders, in particular, industry and academia come closer together, find unifying goals and join forces behind a common vision. This will strengthen European competitiveness and ensure leadership in a future medicine that has single-cell based innovation at its core.

Implementing an Ethically Responsible Strategic Research Agenda

An integral part of developing and implementing LifeTime's SRA involves addressing the ethical questions, relevant to both medical and research communities, and also to citizens, including patients. To prioritise individual interests and foster trust between researchers, clinicians and the public, we propose creating a LifeTime Ethics Mechanism that will co-produce the ethical, legal and societal impact of LifeTime's biomedical innovations. It will identify risk areas and steer research and healthcare innovations into ethically-sound directions and ensure the protection of patients' privacy through regulated data access within Europe. It will also evaluate the societal implications of innovative technologies in research and healthcare and address emerging issues that impact people's life choices. Through awareness and engagement strategies based on transparency and trust, the LifeTime Ethics Mechanism will promote critical thinking and empower citizens to actively engage in decision-making processes and have a voice in strategic decisions.

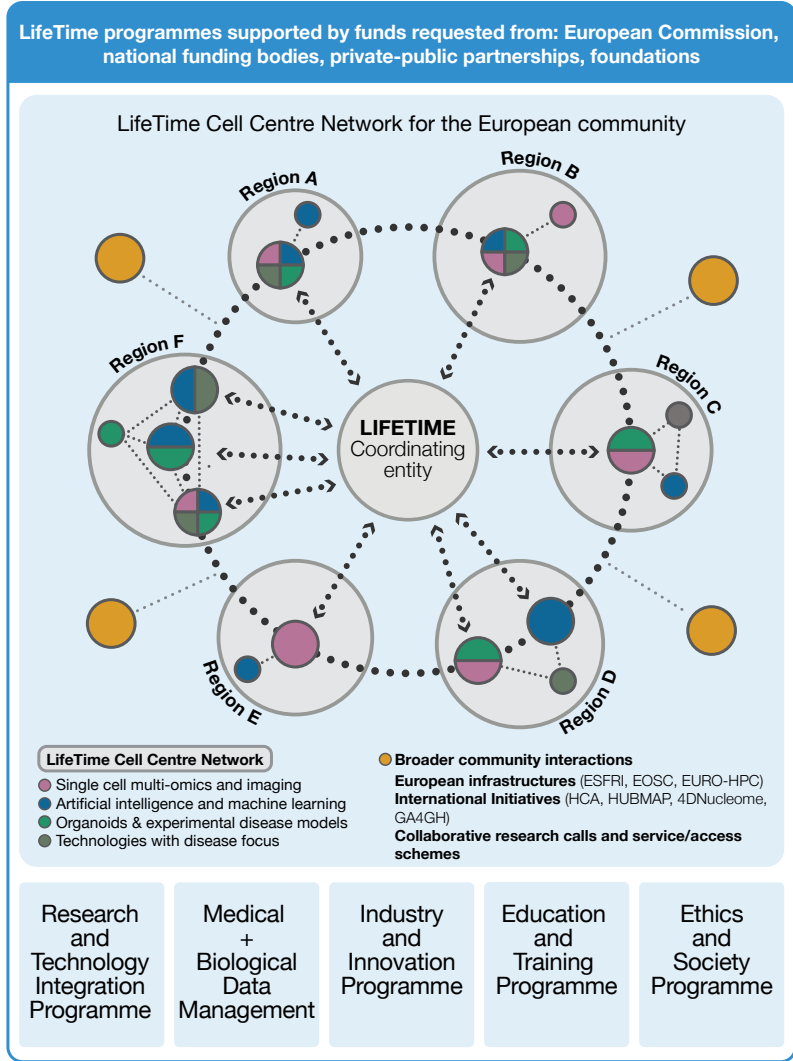
Preparing Europe for Cell-based Interceptive Medicine

Combining and applying knowledge and innovation from various scientific and technological fields and sectors will require professionals with an interdisciplinary, open and creative mindset. Due to limited training opportunities and scarcity of experts in LifeTime's core technology areas, most higher-education European institutions are currently unprepared to face this challenge. A European interdisciplinary Education and Training Programme, based on a culture of lifelong learning and high adaptability to the constantly evolving medical challenges and technology development, will sustainably respond to these needs. LifeTime will develop a programme where scientists, clinicians, managers of technology platforms, research and clinical technical staff or administrators can acquire new skills in technological intersections, cross-sectoral collaborations or communication and bioethics. Committing to a general dissemination of knowledge and to prepare citizens to embrace a new kind of medicine, LifeTime will create a science outreach programme that will contribute to public openness and trust in science. Through education, training and outreach, LifeTime will sustainably prepare its future professionals, will contribute to European scientific and clinical excellence and will support a more knowledgeable and engaged society confident in research, healthcare and innovation.

Realising LifeTime in Europe

LifeTime aims to create the knowledge and necessary conditions to ultimately put cell-based personalised medicine into practice for millions of European citizens. To answer this challenge, we propose to establish a long-term, large-scale research initiative that not only spans across multiple disciplines but also many countries. Sustaining an open and interactive European community, the LifeTime implementation plan is designed to provide flexibility to respond to rapidly developing technology areas while building an active and cooperative research and innovation ecosystem. It builds on existing programmes and recommends the creation of connected infrastructure hubs, the multidisciplinary LifeTime Cell Centres, to generate critical mass, new opportunities for innovative research and clusters of innovation, collaboration and partnership. Closely associated with hospitals, the open network of these centres with synergistic and complementary specialisations will connect the expertise that is necessary to foster the progress of LifeTime technology development.

Everywhere in Europe the Cell Centre network will support interoperability and complementarity and provide cost-effective access of researchers and innovators to the LifeTime technologies. The framework includes a shared biomedical data management programme, a medico-scientific research and technology integration programme, programmes for training and bioethics as well as an open innovation scheme accelerating the translation of knowledge into clinical use. A central coordination body will guarantee cohesion, coherence and collaboration. Complementing and strongly cooperating with projects of the ESFRI Roadmap and other existing national, European and international efforts, LifeTime's consolidated pan-European action plan offers the potential of propelling European science and medicine into a position of global leadership.



LifeTime implementation Blueprint

LifeTime is the large-scale collaborative multidisciplinary research initiative necessary to shape future European healthcare and approach to medicine. Through sustained synergies created with coordinated investments in research and infrastructure by private and public fund injections, we aim to have a transformative impact on the industrial economy, healthcare, and innovation to establish Europe as a leader in cell-based interceptive medicine. Research at the interface of several technologies and medical areas will ensure that Europe attracts the best young talent and established researchers to develop research projects in world-class laboratories, medical centres and innovation clusters. Most importantly, over the next decade LifeTime will enable European patients and the whole of society to benefit from truly personalised, cell-based and effective healthcare interventions.