

# ALGORITHMS IN HEALTH SCIENCES

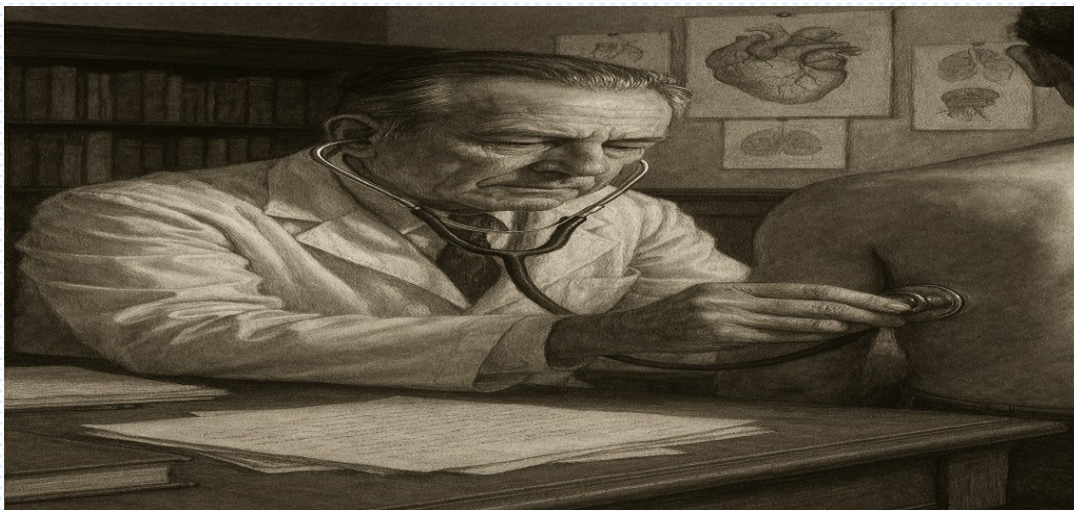
Development perspectives of services, processes  
and technology



## The influence of algorithms on healthcare processes

Health sciences are undergoing a profound transformation. Digitalization, artificial intelligence, and data-driven methodologies have already reshaped the ways in which diseases are diagnosed, treated, and prevented. Algorithms are no longer merely computational tools operating in the background; rather, they constitute the very foundation of innovation in healthcare services, processes, and technological development.

Historically, medicine has relied on the physician's expertise, clinical observations, and empirical research. Today, however, a new actor has emerged: computational intelligence, capable of processing vast datasets, discerning latent patterns, and offering perspectives to support decision-making that would remain inaccessible to human cognition alone. This development is not merely technical in nature; it also represents a cultural and ethical transformation that challenges our conceptions of knowledge, responsibility, and trust.



*The doctor's experience has been the compass of treatment, where knowledge and skill guided decisions.*

Algorithms enable a transition in healthcare services from reactive treatment toward proactive and personalized care. They underpin teleconsultations, mobile health applications, and continuous patient monitoring. At the process level, algorithms optimize resource use, predict patient flows, and help target care where it is most needed.

Algorithms not only optimize technical processes, but also transform the division of labor, decision-making, and patient experience in nursing. Algorithms automate routine tasks and free up professionals' time for complex clinical assessments, provide flexibility for real-time risk assessment and treatment recommendations, guide patient pathways based on prioritization and resource allocation, and create a closed feedback loop where data accumulated from use continuously improves models.





Open-source ecosystems facilitate rapid dissemination, collaborative development, and independent auditing of algorithms. International consortia and networks, such as OHDSI and HL7, provide platforms for shared standards, data models, and the exchange of best practices. These communities reduce development costs, ensure algorithmic transparency, and deliver continuous feedback from a broad base of researchers and users. Global developer communities on platforms such as GitHub and GitLab bring together scientists, healthcare professionals, and software teams, thereby creating a dynamic development loop that accelerates the piloting and implementation of innovations. Such openness and international collaboration strengthen the reliability, safety, and acceptability of algorithms within healthcare services.

## The role of algorithms in reshaping the knowledge base

Algorithms can be understood as recipes for computers, precise instructions that define how a task is executed step by step. They constitute a fundamental element of computer science and exert influence across virtually all domains. Increasingly, diverse data sources such as genomics, sensor outputs, lifestyle information, and patients' clinical histories are being integrated, enabling the development of more sophisticated and versatile algorithms.

A multidisciplinary team brings together complementary expertise: physicians articulate clinical needs and safeguard patient safety; data scientists ensure data quality, design and validate models, and provide interpretability of algorithmic processes; and data protection officers oversee the privacy of patient information, assess algorithmic fairness, and ensure compliance with regulatory frameworks.



*Preventive care, individually and effectively.*



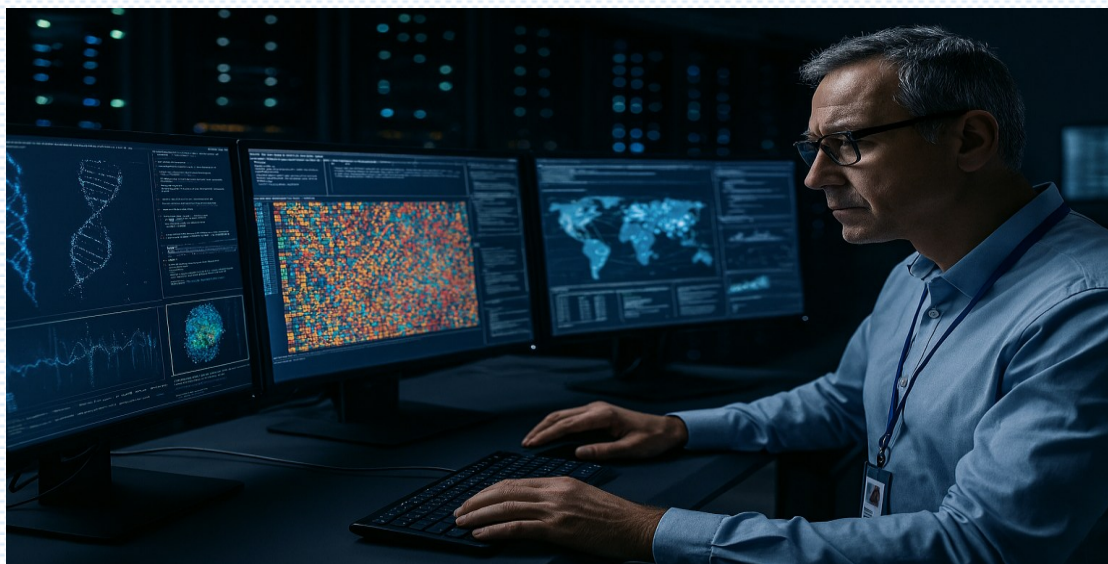
Digital twin models and the Internet of Medical Things (IoMT) have transformed healthcare by advancing it toward individualized and predictive care. A digital twin constitutes a virtual representation of a patient, continuously updated in real time through health data collected by IoMT devices such as sensors and smart technologies. These models enable the simulation of physiological functions, the forecasting of disease progression, and the evaluation of potential treatment outcomes prior to their implementation.

IoMT further facilitates continuous patient monitoring and the optimization of care delivery beyond the confines of hospital settings. This development is propelled by advances in artificial intelligence, high-performance computing, and increasingly rapid communication networks. Nevertheless, significant challenges remain, particularly in relation to data security, ownership of health information, and the interoperability of systems.

## Supercomputers

Supercomputers have opened a new dimension in the processing and analysis of healthcare data. Their immense computational power enables models and simulations that were previously unattainable. This capability has fundamentally reshaped approaches to disease diagnosis, drug development, and the optimization of care pathways.

Algorithms analyze patient information such as laboratory results, imaging data, and medical histories, supporting physicians in making more accurate diagnoses with greater efficiency. Machine learning models can detect early indicators of disease, including risk factors for cancer or cardiovascular conditions, before they manifest clinically. Algorithms also facilitate the design of individualized care pathways by integrating patients' genetic backgrounds, lifestyle factors, and prior treatment outcomes.



*Genomes are being unlocked, and medicine is ascending to a new level.*





The development prospects of supercomputer algorithms in the health sciences are highly promising, as increasing computational power enables the modeling, analysis, and prediction of increasingly complex biological and medical phenomena. Supercomputers are particularly utilized in advancing genomics and personalized medicine, where vast genomic datasets are analyzed to identify connections between diseases and genetic variations. They also accelerate the training of artificial intelligence and machine learning algorithms, thereby enhancing diagnostics, imaging analysis, and the predictability of treatment outcomes.

High-performance computing supports the modeling of protein structures and drug development, allowing for precise simulations of drug interactions and molecular dynamics. Emerging biomedical simulations, such as the digital twin of the human body, provide novel tools for the design of individualized care. The convergence of supercomputing and quantum computing opens new possibilities for real-time biological simulation and faster, patient-specific healthcare delivery.

## Quantum computers

For years, supercomputer algorithms have enabled the processing of genomic data, imaging datasets, and epidemiological models. Attention is now shifting toward quantum computing, whose algorithms promise to address problems that classical computation cannot efficiently manage. Quantum computing facilitates the modeling of drug structures, the resolution of complex optimization challenges, and the accelerated solution of intricate biological, chemical, and medical problems far more rapidly than traditional computers.



*Solutions to the impossible, faster diagnostics and drug development.*



Quantum algorithms are being developed particularly for the modeling of drug and protein structures, where they can simulate atomic and molecular interactions with quantum-mechanical precision. This significantly accelerates drug screening processes and reduces research costs. Quantum computing also offers new opportunities for addressing computational challenges in genomics and bioinformatics, such as the analysis of vast DNA sequence datasets and the identification of genetic risk factors for diseases.

Quantum and machine learning algorithms are increasingly being combined, giving rise to quantum artificial intelligence models capable of processing large and multidimensional health data sets. These may include patient genomic information, imaging data, and lifestyle records, from which novel connections can be identified to improve disease prediction and diagnosis. Quantum algorithms are poised to revolutionize disease modeling and the optimization of treatment strategies. Quantum simulations enable the modeling of phenomena such as cardiac electrical activity, neural networks, or tumor growth in ways that account for quantum-level interactions within biological processes.

At the same time, 6G technology opens the possibility for real-time, near-zero latency data transmission. This provides the foundation for applications in which artificial intelligence and algorithms operate seamlessly as part of clinical practice, ranging from remote surgery to the continuous analysis of biosensor data. When 6G converges with artificial intelligence and quantum computing, it creates an ecosystem that transforms the infrastructure of healthcare.



*The future of clinical work: speed, accuracy and intelligence.*





In the optimization of drug and treatment trials, quantum computing accelerates the modeling of complex molecular interactions, artificial intelligence identifies the most promising compounds, and 6G technology transmits trial results in real time. In personalized medicine, quantum-assisted optimization algorithms map treatment pathways based on patient profiles, artificial intelligence predicts therapeutic responses, and 6G enables the decentralized collection of sensor data.

Examples of quantum algorithms in healthcare:

### **HHL Algorithm (Harrow–Hassidim–Lloyd)**

Solves large linear systems exponentially faster than classical methods.

*Application:* Reconstruction of MRI and CT images, where matrix transformations of imaging signals are efficiently resolved within a quantum framework.

### **VQE (Variational Quantum Eigensolver)**

Searches for the lowest energy state of a quantum molecule using hybrid quantum–classical optimization.

*Application:* Simulation of novel drug molecular structures and estimation of interaction energies.

### **QAOA (Quantum Approximate Optimization Algorithm)**

Provides near-optimal solutions to discrete optimization problems in short computational time.

*Application:* Optimization of radiation therapy dosage and targeting, as well as resource allocation in hospital logistics.

### **Quantum Machine Learning Algorithms**

Examples include QSVM (Quantum Support Vector Machine) and qk-NN (quantum k-Nearest Neighbors).

*Application:* Genomic classification, patient risk profiling, and detection of rare biomarker combinations.

### **QFT (Quantum Fourier Transform)**

Performs efficient Fourier transforms in quantum states.

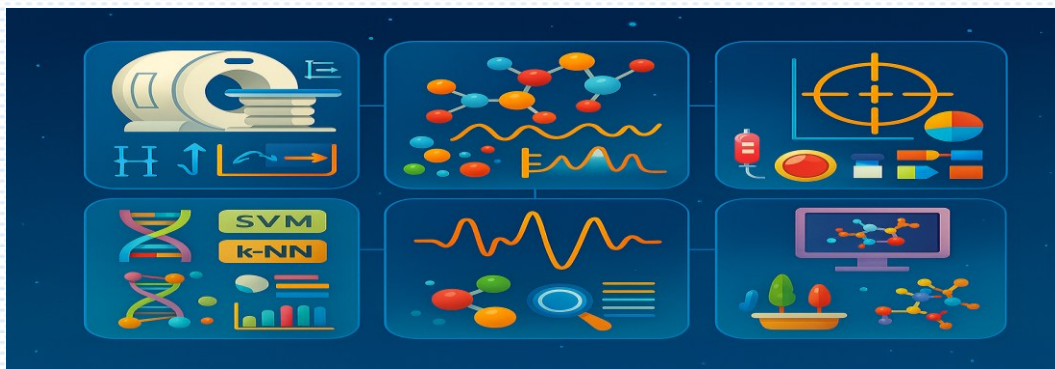
*Application:* Frequency analysis of physiological signals such as EEG and ECG, including noise separation.

### **Quantum Monte Carlo Simulations**

A stochastic simulation technique leveraging quantum mechanics.

*Application:* Computational prediction of protein structures and precise modeling of cellular-level interactions.





*The healthcare infrastructure is changing.*

Examples of quantum platforms in health sciences:

#### **Google Quantum AI: Quantum Echoes Algorithm**

Provides enhanced speed for molecular simulations.

#### **IBM Qiskit Health**

An open platform dedicated to quantum medicine research.

#### **National Quantum Computing Centre (UK)**

Hosts more than forty applications in diagnostics, drug development, and treatment optimization.

### **Biocomputers and adaptive biological systems**

Biocomputers integrate the properties of living cells, biomolecules, and computational systems, opening new avenues for measuring, modeling, and directing biological processes and their interfaces with technical systems. Biological systems exhibit learning capacity because they consist of millions of locally operating units, such as neurons and synapses, which alter their connections and modes of operation based on experience. These units function simultaneously, in a distributed and adaptive manner, which provides the system with flexibility, fault tolerance, and the ability to generalize in uncertain environments.

Biocomputers and biological computing systems introduce a new era in the health sciences by integrating biology, information technology, and synthetic biotechnology. Biocomputers employ living components such as DNA, RNA, and cellular networks for information processing through biochemical reactions, enabling parallel and energy-efficient computation. In health sciences, they are being developed particularly for disease diagnostics, intelligent drug delivery systems, and cellular programmability. For example, a biological algorithm may detect a disease-associated biomarker and release a therapeutic agent precisely at the targeted cellular site.







*The power of cells in computing: intelligent drug delivery and new treatment models.*

Brain organoids are three-dimensional, stem cell–derived miniature brain structures that replicate aspects of human brain development and functional properties under laboratory conditions. Although they are not fully developed brains, they contain neurons, synapses, and electrical activity that resemble the processes occurring in the developing human brain. They enable the investigation of how genetic alterations, pharmacological agents, or environmental factors influence neural development and function in human-derived tissue. Brain organoids provide a valuable research tool particularly for modeling neurological and psychiatric disorders, including autism spectrum disorders, epilepsy, Alzheimer’s disease, Parkinson’s disease, and brain tumors.

FinalSpark’s Neuroplatform is the world’s first remotely accessible biocomputing platform, specifically designed for energy-efficient artificial intelligence research, neural network modeling, and bio-algorithm development. The platform utilizes 16 human brain organoids that act as biological processors. These can be used to simulate and test learning, memory, and computation using nature’s own mechanisms. Researchers around the world can log on to the platform and conduct experiments with biological neurons without having to grow the cells themselves.

Biocomputer algorithms have moved from theory to practice. The first commercial systems are already available, and bio-inspired algorithms focus on energy efficiency, data minimization, and sustainable computing. Biocomputer algorithms are moving towards a hybrid model that combines biological dynamic computing with electronic and programmatic control. In the near future, rapid advances can be expected at the prototype level and in applications where the unique properties of biology: parallelism, adaptation, and energy efficiency bring a clear advantage. The development of algorithms focuses on reliability and usability from laboratory conditions to field and production environments. Biocomputers can act as intelligent systems within the body that analyze, learn, and respond to biological changes in real time.



## Towards proactive and personalized healthcare

The development of healthcare algorithms is not merely a technical innovation but a comprehensive transformation that reshapes our understanding of health, knowledge, and responsibility. When computational intelligence converges with biological systems, a new ecosystem emerges in which care is no longer confined to hospital environments but extends into everyday life, lifestyle practices, and continuous individual monitoring. This opens possibilities for predictive and personalized care, while simultaneously requiring strong ethical guidance, transparency, and international collaboration.



*Proactive care starts with data and intelligent analysis.*

Ultimately, algorithms form a bridge between humans and machines: they do not replace clinical expertise but rather strengthen it by providing new perspectives and tools. The healthcare of the future will be built upon this synergy, in the interplay of technology and biology, with the aim of achieving more sustainable, equitable, and humane health for all.