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COMPUTATIONAL MEDICINE – MOVING FROM UNCERTAINTY TO PRECISION

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Abstract

Computational Medicine (CM) is an emerging discipline devoted to application of mathematics, engineering, and computational science to develop quantitative ways for understanding the processes, diagnosis, and treatment of human disease. CM's main goal is to create computational models of disease's molecular biology, physiology, and anatomy, and then use these models to improve patient care. Many fields of biology, including genetics, genomics, molecular networks, cellular and tissue physiology, organ systems, and whole-body pharmacology, can benefit from CM techniques. This paper introduces the concepts and characteristics of computational medicine and then reviews the relevance of the characteristics of computational medicine.

Keywords: *Computational medicine, Computational models, Diagnosis, Treatment*

INTRODUCTION

Medicine at its core, is decision-making in the face of uncertainty; decisions are made about which tests to undertake and which treatments to deliver. Traditionally, uncertainty in decision-making was addressed by individual physicians' knowledge and, more recently, systematic research appraisal in the form of evidence-based medicine. For a long time, the traditional technique has been employed successfully in medicine. However, due to the complexity of the human body and healthcare systems, it has significant limits. Complex systems are made up of a network of strongly connected components that are constantly interacting. These interactions provide redundancy and consequently failure resistance to those systems, as well as equifinality for many causation pathways to lead to the same result. Individualization of medical care, medicine, and medical decision-making is required by the equifinality of the complex systems of the human body and healthcare system.

Scientists can now discover, study, and compare the fundamental biological components and processes that regulate human diseases and their consequences thanks to powerful computational platforms. Traditional evidence-based medicine, which relies on personal testimony to guide testing and prescriptions, is a one-size-fits-all method that will eventually be supplanted with predictive, continuous, numerical health claims.

Improved patient outcomes are also aided by advances in modelling and simulation. The medical industry has been revolutionized by information technology in recent decades. The precision with which biological systems and interactions may be simulated and data collected

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has increased by orders of magnitude. Computational medicine has supplied medical researchers with increasingly sophisticated data.

Computational medicine, in a nutshell, calculates and models the activity processes of organisms at the molecular, gene, cell, organ, and tissue levels at various time and space scales. This method may be used to get a more realistic understanding of the mechanics of life and illness, as well as a scientific and efficient strategy to enhance disease prediction, clinical diagnosis, treatment, and health maintenance. The objective is to enhance illness prediction, diagnose and treat patients more effectively, design, create curative effect assessments, engage in novel medication research and evaluation, and give "individualized" diagnosis and treatment. The intersection of computational medicine and artificial intelligence is a key avenue for clinical decision support system enhancement and development.

Characteristics of computational medicine

Computational medicine is methodical and data-driven. In methodological and clinical research, computational medicine provides distinct benefits over traditional medical research methodologies.

- **Data Intensive**

Biomedical big data may be utilised to address difficult clinical problems and provide tailored health care services by mining new insights in the data and employing a data- and knowledge-driven fusion calculating approach.

- **Artificial intelligence**

In the biomedical discipline, the knowledge model is turned into a mathematical model. As input parameters, biomedical big data is employed. The model is iterated and trained using an artificial intelligence algorithm. To comprehend the nature of illness incidence, the output is near to the real-life system structure and functional features. Artificial intelligence can parameterize each patient's life data (including molecules, pictures, tissues, and organs) and create unique equations for them.

- **Systematic thinking**

The holistic theory of complexity science is employed as a method of thinking to explain "developing" new qualities in the interaction between molecules, cells, tissues, organs, and populations, as well as to capture disease occurrence mechanisms from a systematic viewpoint.

- **High performance computing**

In terms of size, biomedical big data has surpassed the petabyte mark. Data intensive scientific paradigms require significant computer resources and processing power to uncover new information. High-throughput, multi-task computing requires a high-performance computing environment that can handle data storage, computation precision, and computing speed.

Advantages of Computational medicine over current system

Current System	Computational Medicine

The flaws of reductionism are becoming more apparent: the first is that the refining of distinct disciplinary branches is generating barriers to knowledge flow; the second is oversimplification. In the past, reductionist research approaches in medicine lost at least some information on interactions between different components of the life system, as well as non-linear aspects of the life system's structure and function along the time axis.	The varied activities of complex multi-level networks and the whole complex biological systems that coordinate these networks together are addressed in this medical field. From a systemic viewpoint, computational medicine uses the holism of systems science as the style of thought to capture the process of illness incidence and progression.
Clinical data is fragmentary and convoluted, and clinical diagnosis is based on clinicians' reasoning and judgement. When using traditional biological methods to analyze diseases, it is difficult to avoid error in	This medical discipline deals with the many activities of complex multi-level networks as well as the entire complex biological systems that coordinate these networks. Computational medicine, from a systems perspective,
Clinical diagnosis and treatment due to a lack of information extraction and the doctor level.	employs the holism of systems science as a way of thinking to capture the process of sickness onset and development.
Health and disease biology is extremely complicated. It entails the information flow from genes to proteins, networks, cells, tissues, organs, and organ systems.	Medical researchers may use computational models to better understand the nature of these exceedingly complex and perplexing diseases, as well as diagnose and assess the efficacy of various treatments. The results of the tests can be utilised to improve the model's predictability.
Precision medicine will use a knowledge network to deliver accurate disease prevention, diagnosis, treatment, and even health advice. However, correct integration of diverse highly connected biological, medical, and health information, as well as the construction of databases and accompanying decision support systems, are challenging to achieve in the short term. Precision medicine will be a tough procedure to enhance human health because of the complexity of the environment and disease.	We will look at life systematically, use computer-aided technology to build physiological and pathological models, use supercomputing to mine big biological data for new key points, and continuously optimize dynamic model construction by combining with artificial intelligence to explore the correlation in the whole-body system under the computational medicine methodology.

Computational models

Computational models aid in the understanding of these complicated interactions, which are frequently complex and non-intuitive in nature. Researchers may use models like this to better understand illness causes, help in diagnosis, and evaluate the efficacy of various medicines. The findings may then be used to direct further trials to collect fresh data and tweak the models until they are highly predictive.

- Advanced mathematical models are allowing researchers to better understand how networks of molecules are implicated in cancer and then use this knowledge to predict which patients are at risk of developing the disease.
- A discipline called computational physiological medicine is using computer models to look at how biological systems change over time from a healthy to an unhealthy state. This approach is being used to help develop better treatments for cancer, diabetes and heart disease.
- Computational anatomy uses medical images to detect changes, for example, in the shape of various structures in the brain. Researchers have found shape changes that appear to be associated with Alzheimer's disease and neuropsychiatric disorders, such as schizophrenia.
- Computational models of electrical activity in the heart are on their way to being used to guide doctors in preventing sudden cardiac death and in diagnosing and treating those at risk for it.

Future Prospects

Computational anatomy, based on anatomical information and employing image processing, digital geometry, mathematical modelling, and virtual reality, is the first use of computational medicine in the clinic. It examines biological morphological variation quantitatively, human body structure modelling, surgical planning, stereotactic surgery, precision radiotherapy, image navigation surgery, robotic surgery, and the morphology and function of the nervous system. Computer-aided bioprinting microvessels, for example, have several uses in disease modelling and medication testing. Computational physiology, epidemiology, pharmacology, and other basic sciences, as well as fields with important program components, such as computational surgery, may take longer to incorporate operations based on computational medicine technology.

Computational medicine focuses on data models for operational prediction, whereas artificial intelligence relies on data information to rule summaries. Computer-based systems have their own benefits and complement one another. When computational medicine, artificial intelligence, and clinicians collaborate, a synergistic impact is created that is superior to each one or all of them alone, which will undoubtedly transform clinical decision-making.

The clinical diagnostic and treatment procedure will be optimized in the era of computational medicine. Clinical medical workers can focus on global clinical management, such as personalized drug side effect management, postoperative management, rehabilitation program management, emergency management, prognosis management, follow-up, and accurate definitions of individualized rehabilitation indicators, in addition to accurately guiding the implementation of treatment plans. The computational medicine model-building system provides a useful experimental simulation tool for future scientific study. This approach can personalize disease evolution models-Based on the needs of clinical medicine and scientific research, computational medicine should adhere to two research directions. One is to apply information science to life science and medical Research and adopt a data-driven learning method to understand the mechanisms of diseases and explore new drug targets and treatment schemes; the other is to review the knowledge of professional fields comprehensively by establishing a man-machine interface and summarize and establish a knowledge model.

Conclusion

The information age has arrived in modern civilization, and biomedical data in the medical industry has reached the Petabyte level. To break through the current "bottleneck," the biomedical field must speed up the construction of the new digital infrastructure that underpins computational medicine, emphasize the role of computational power, artificial intelligence methods, and big data, and utilize the value of biomedical big data. All associated practical computational medicine research is progressing quickly, however while computational medicine theory is potent, clinical applications are scarce. Although we are aware that the circumstances will soon change and that the implementation of this technology will become unavoidable, the question is not whether it will happen, but when.

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