

# BIOMEDICAL ENGINEERING (BME) AND MEDICAL HEALTH SCIENCE: AN INVESTIGATION PERSPECTIVE EXPLORATION

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**Abstract.** In the ever-evolving landscape, rapid advancements within the domains surrounding technological computing have brought about significant growth and transformation in the various types of biomedical engineering (BME) domains of engineering, medical engineering, health informatics particularly in the field of medical science and human health. With the accelerated progress in computer vision, image processing, machine learning, deep learning, and especially data science, there has been a booming revolutionary change in healthcare, addressing towards a wide range of the medical conditions and human anatomy perspectives. The integration of these technologies has not only improved medication and disease control but has also provided solutions for complex tasks and issues related to human anatomy threats in the medical health sector. This research focuses on the impact of these various types of innovative accelerated computing in biomedical engineering, providing insights into the modern utility of toolsets in line with Bioinformatics, Biomedical Applications and mechanics with artificial intelligence (AI) within medical science and also diving into a much deeper understanding towards the human anatomy. It also explores the concept of functional genomics and its potential to provide insights into future disease and health issues, paving the way for advancements in medical healthcare for the foreseeable future and beyond.

**Keywords:** *Artificial Intelligence (AI), Biomedical Engineering (BME), bioinformatics, biomedical imaging, data science, Deep Learning (DL)*

## Introduction

The context of this research revolves around all the various domains associated within the realm of biomedical engineering. Biomedical engineering, also known as medical engineering, combines principles of engineering and design with medicine and biology to address healthcare challenges. It encompasses a wide range of applications, including diagnostics, therapy, and the management of medical equipment in hospitals. As a relatively new field, biomedical engineering has evolved from an interdisciplinary specialization to become a distinct discipline. Much of the work in this field involves research and development in various subfields (Akhtar, 2024). Biomedical engineers contribute to advancements such as biocompatible prostheses, medical devices for diagnosis and treatment, imaging technologies like MRIs and EKG/ECG/EEGs, regenerative tissue growth, and the development of pharmaceutical drugs and therapeutic biologicals (Akhtar and Gupta, 2024a; 2024b; Akhtar, 2024; 2022; Akhtar and Rozario, 2020). The field of biomedical engineering plays a crucial role in advancing healthcare and improving patient outcomes. Biological engineering, also known as bioengineering, applies the principles of biology and engineering to develop practical and economically viable products. This field draws knowledge and expertise from various scientific disciplines, including mass and heat transfer, kinetics, biocatalysts, biomechanics, bioinformatics, and more. It encompasses the design of medical devices, diagnostic equipment, biocompatible materials, renewable energy systems, ecological engineering solutions, agricultural engineering advancements, and catalysis processes. Bioengineering research includes the development of engineered

bacteria for chemical production, innovative medical imaging technologies, portable disease diagnostic devices, prosthetics, biopharmaceuticals, and tissue-engineered organs (Akhtar and Gupta, 2024a; 2024b; Akhtar and Rozario, 2020). Bioengineering intersects with biotechnology and biomedical sciences, similar to how other engineering fields relate to various scientific domains. Bioengineers also collaborate with doctors, clinicians, and researchers to mimic or modify biological systems, applying engineering principles to replace, enhance, sustain, or predict chemical and mechanical processes within the biological realm.

Biomedical engineering has emerged as a distinct and specialized field within engineering. It has transitioned from being an interdisciplinary specialization to being considered a field in itself. The majority of work in biomedical engineering revolves around research and development across various engineering subfields. Prominent applications of biomedical engineering include all the development of biocompatible prostheses, diagnostic and therapeutic medical devices, imaging technologies like MRI and ECG and EEG, regenerative tissue growth, and pharmaceutical drugs and therapeutic biologicals to a certain degree (Akhtar and Rozario, 2020). Biomedical engineering involves collaboration among technologists, biologists, and medical professionals. Its primary goal is to acquire fundamental knowledge about the physical characteristics and functioning of biological materials. This knowledge is then applied to create devices, perform surgeries, and develop new techniques that enhance people's health and overall quality of life. Notable achievements within the biomedical engineering resulting from this collaboration include dialysis machines for kidney replacement, hip and knee prostheses, materials and technologies for heart and blood vessel surgeries, and artificial hearts. These advancements have significantly contributed to improving healthcare outcomes and have positively impacted the lives of individuals around the world.

### ***Back ground research and iterative exploration for available knowledge***

Bioengineering is an interdisciplinary field that applies engineering principles to solve problems in the life sciences. Throughout history, the design and production of medical devices, including prosthetic devices, have been prevalent. Examples of ancient prosthetics, such as wooden digits found in Egyptian tombs, highlight early attempts to replace missing body parts. In the late 1700s, Luigi Galvani's experiments explored the relationship between electricity and animal physiology. This paved the way for using electrical impulses within the body for diagnostic purposes, as seen in the field of electro cardiology. Galvani's student, Alessandro Volta, later invented the first battery in the early 18th century, leading to the application of electricity for therapeutic uses. Additionally, Wilhelm Roentgen's discovery of X-rays in the 19th century revolutionized diagnostic procedures by utilizing electromagnetic radiation. In the 20th century, the world witnessed remarkable discoveries and breakthroughs in bioengineering. Mechanical, electrical, and chemical engineering principles converged to create complex medical systems. These advancements included the development of dialysis, pacemakers, artificial hearts, responsive prosthetic devices, and DNA testing that underlies within various genetic technologies (Goyal, 2018; Pasotti and Zucca, 2014; Enderle and Bronzino, 2011; Ryerson University, 2011; Couvreur and Vauthier, 2006; Curtis et al., 2006; Cuello, 2005; Kassab, 2004; WHO, 2003; Johnson and Phillips, 1995; Roesler, 1987). As we enter the 21st century, bioengineering remains a dynamic field for technological breakthroughs and exciting new developments that hold

the potential to significantly enhance the quality of life. Biological engineering is a discipline rooted in the biological sciences, similar to how other engineering fields are based on specific scientific principles. The term "bioengineering" was coined in 1954 by scientist Heinz Wolff, marking the recognition of this field as a distinct branch of engineering. Initially, bioengineering focused on electrical engineering due to its application in medical devices and machinery.

As engineers and life scientists collaborated, they realized the need for a deeper understanding of biology in engineering work. This led engineers interested in biological engineering to devote more time to studying biology, psychology, and medicine to enhance their knowledge in these areas. In recent years, the term biological engineering has also been applied to environmental modifications aimed at soil protection, slope stabilization, watercourse management, and ecological enhancement (Hart et al., 2015; Galas, 2015; Gilbert et al., 2014; Kwasnieski et al., 2014; Arnold et al., 2013; Graur et al., 2013; Wang et al., 2011; Vincent et al., 2006; Subramanian et al., 2005; Fields and Song, 1989). Agricultural engineering has also been encompassed within biological engineering due to their shared focus on living organisms. The first biological engineering program in the United States was established at the University of California, San Diego in 1966, followed by similar programs at MIT and Utah State University. Many agricultural engineering departments worldwide have also rebranded themselves as agricultural and biological engineering or agricultural and biosystems engineering. Biological engineering spans a wide range of scales and complexities, applying engineering principles to systems ranging from the molecular level (such as molecular biology and biochemistry) to cellular and tissue-based systems (including devices and sensors) to whole organisms and even entire ecosystems (GTEx Consortium Lead Analysts, 2017).

It encompasses various fields, including microbiology, pharmacology, immunology, neurobiology, and neuroscience, and offers a broad base of knowledge to address diverse biological challenges. Bioinformatics is an interdisciplinary field that focuses on developing methods and software tools to analyze and interpret biological data. It combines computer science, statistics, mathematics, and engineering to unravel the complexities of biological information (Diss and Lehner, 2018; Li et al., 2018). As an umbrella term, bioinformatics encompasses a broad range of biological studies that utilize computer programming as a crucial part of their methodology. It also refers to specific analysis "pipelines" that are commonly used, particularly in the field of genomics. Bioinformatics plays a vital role in identifying candidate genes and nucleotides, such as single nucleotide polymorphisms (SNPs) (Mardis, 2008; Fiers et al., 1978; Nirenberg et al., 1965). The identification of these genetic variations helps in understanding the genetic basis of diseases, unique adaptations, desirable traits in agricultural species, and differences between populations. Beyond its practical applications, bioinformatics also seeks to uncover the underlying organizational principles within nucleic acid and protein sequences (Kooimey et al., 2010; Dougherty, 2009; Jha et al., 2009; Miller, 1994; Baxt, 1991; Buchanan and Shortliffe, 1984; Duda and Shortliffe, 1983). By studying the patterns and structures of these biological molecules, researchers aim to gain insights into their functions and evolutionary relationships. In other words, bioinformatics serves as a powerful tool in biological research, enabling scientists to analyze large-scale biological datasets, identify genetic variations, and explore the organization and function of biological molecules. It contributes to advancing our understanding of various biological phenomena and has

significant implications in fields such as medicine, agriculture, and evolutionary biology (Jain, 2023; Bahl et al., 2018; Power, 2015).

Biomedical engineering encompasses various subfields that contribute to advancing healthcare and improving human well-being. Biomechanics focuses on studying the mechanical aspects of biological systems at different levels, from whole organisms to cell organelles, using principles of mechanics. Biomaterials science explores the interaction of materials with living systems and has applications in medicine, biology, tissue engineering, and materials science (Wang et al., 2021). Biomedical optics combines physics, engineering, and biology to study the interaction of biological tissue and light for sensing, imaging, and treatment purposes. Tissue engineering aims to create artificial organs and tissues for transplantation, utilizing biological materials and engineering techniques (Chen et al., 2021; Infante et al., 2021; Sotirakos et al., 2021). Genetic engineering involves the direct manipulation of an organism's genes, finding applications in various fields such as crop improvement and the production of pharmaceuticals. Neural engineering focuses on understanding, repairing, replacing, or enhancing neural systems using engineering approaches (Chan et al., 2020; PR Newswire Web Portal, 2020). Pharmaceutical engineering is an interdisciplinary science that combines drug engineering, drug delivery systems, pharmaceutical technology, chemical engineering operations, and pharmaceutical analysis to improve medicinal treatment. Each of these subfields contributes to the advancement of biomedical engineering and has the potential to significantly impact healthcare and quality of life.

Functional genomics is a field within molecular biology that aims to understand the functions and interactions of genes and proteins. It utilizes the vast amount of data generated by genomic and transcriptomic projects, focusing on dynamic aspects such as gene transcription, translation, regulation of gene expression, and protein-protein interactions. Unlike the static aspects of genomic information, such as DNA sequence, functional genomics takes a genome-wide approach to study these questions using high-throughput methods. The definition of function in functional genomics is often based on the "causal role" of a gene or protein, referring to its sufficiency and necessity for a particular function. The goal of functional genomics is to comprehensively understand the functions of genes and proteins, aiming to eventually encompass all components of a genome. This includes studying the biochemical, cellular, physiological properties, and natural genetic variations of genes and proteins. Functional genomics encompasses various techniques and applications. It involves studying aspects of the genome itself, such as mutations and polymorphisms, as well as measuring molecular activities using techniques like transcriptomics, proteomics, and metabolomics. Multiplex techniques are commonly used to measure the abundance of gene products or analyze the effects of gene variants and mutants. By integrating these measurements, functional genomics seeks to provide a more comprehensive understanding of how the genome specifies function and contributes to systems biology approaches. Functional genomics plays a crucial role in unraveling the complex functions and interactions of genes and proteins, providing insights into biological processes and improving our understanding of various diseases and biological systems.

## Materials and Methods

For the conduction of this research various methods were applied to formulate the optimum perspective results and data analytics with visual representations which is

included regarding the context of this research. The methodology and methods were processed within a step-by-step systematic iterative approach towards the investigation that revolves around the impact of Artificial Intelligence (AI) and Accelerated Computing functionality within Biomedical peripheral systems within the landscape of Biomedical Engineering (BME). To start, a very detailed and comprehensive background iterative research was conducted towards the gathering of the existing knowledge and along with that, available potential context which are identifiable in terms of research gaps. Next, the required data information and its processable collection were mapped inside the KNIME data analytics platform which was convoluted in terms of data mining, performed using different methods with a wide range of functionality tools, and all the sampled data also underwent preprocessing with post processing to ensure that, the quality remained with optimum relevance associated with the perspective domains.

Afterwards, all the performance analytics with visualization representations for those functionality techniques were programmed into design illustration prototyping which were evaluated using suitable metrics and then compared with a variety of traditional and existing technical computing approaches. After that, all the produced results were analyzed, interpreted in the context of the research objectives, with a discussion towards the implications for AI and all the advancements within Biomedical Engineering in line with Accelerated Computing which resulted in many future speculations. Finally, all the findings were summarized and all limitations were acknowledged with suggestions for any type of future research prospect in the respective domain were also mentioned. In other words, this methodology actually enabled a comprehensive exploration of how the designed prototyping toolsets and Accelerated Computing features can enhance the Biomedical Engineering perspective and how AI falls within the digital world, paving the way for a better and improved terminologies with promising outcomes and advancements in the field.

## **Results and Discussion**

### ***Biomedical Engineering (BME) on the advancements towards health informatics***

The field of biomedical engineering has made significant advancements in recent years, leveraging technology, medicine, and resources to address a wide range of health issues. This has fostered an environment that inspires creativity and innovation, enabling biomedical engineers to create solutions that have never been possible before, ultimately improving the lives of billions of people worldwide. One area where biomedical engineering has made tremendous progress is within the development of the healthcare inventions. Biomedical engineers have designed groundbreaking technologies such as prosthetic limbs, artificial hearts, bionic contact lenses, and even the camera pill, which can capture internal processes using a built-in camera, battery, light, and transmitter. These inventions have revolutionized the way we approach healthcare and provide individuals with previously unimaginable solutions to their specific healthcare needs. The impact of biomedical engineering is not limited to inventions alone. Through their research into bodily functions, biomedical engineers contribute to the development of new medicines and drugs to treat diseases, including cancer. They have also played a key role in advancing medical procedures such as laser surgery, offering long-term solutions to health problems that were once considered challenging to address. To give an idea concerning the matter Figure 1 provides a

visualization of physical and cyber healthcare systems with Figure 2 providing an overview of the healthcare data spectrum.

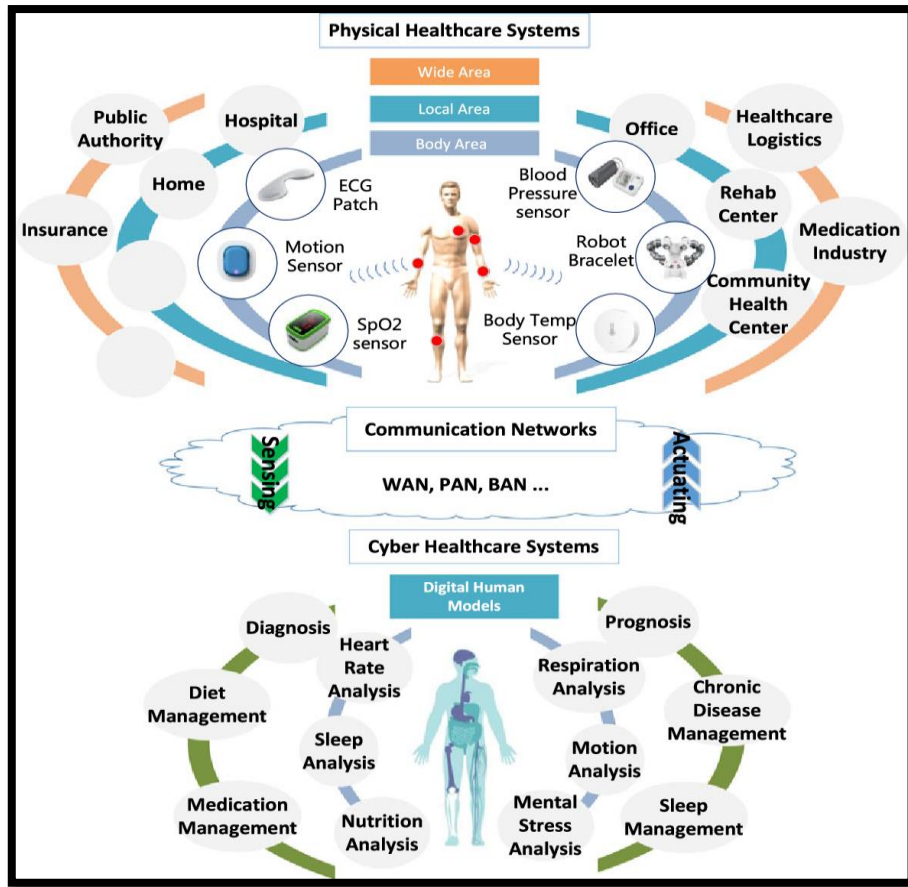
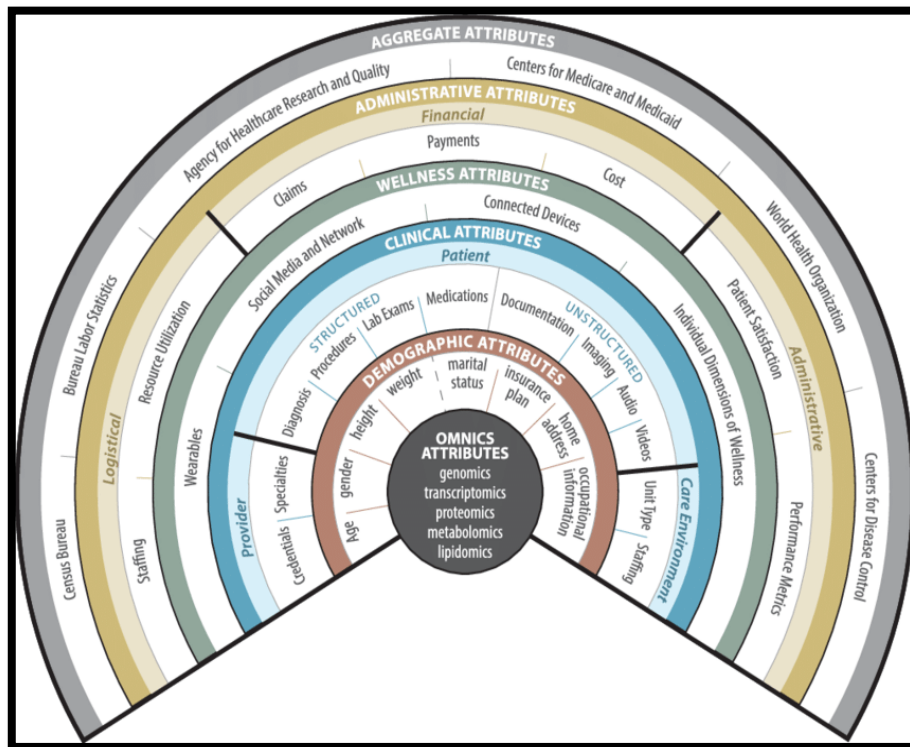


Figure 1. A visualization of healthcare systems.



**Figure 2.** An overview of healthcare data spectrum.

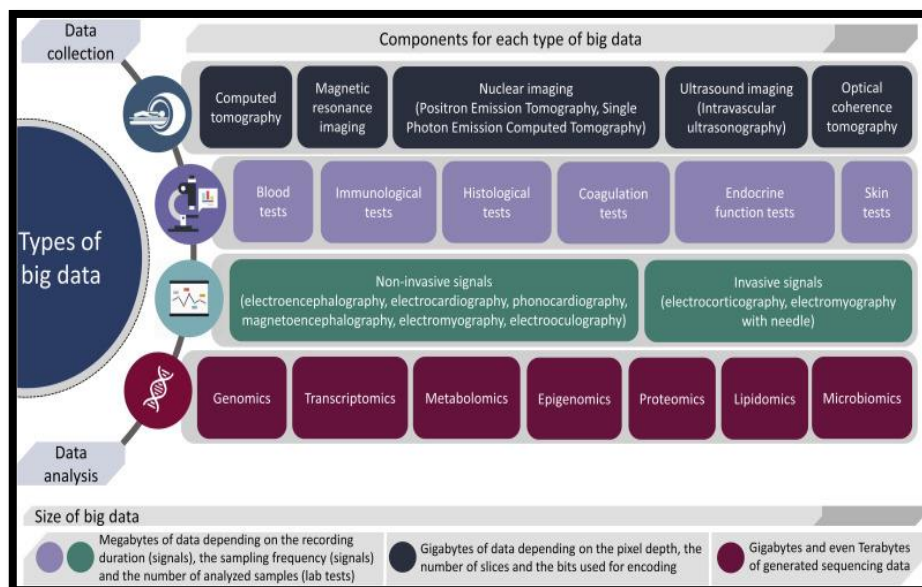
Collaboration between biomedical engineers and other healthcare professionals, such as doctors, nurses, surgeons, and technicians, has resulted in the creation of essential tools and devices. This includes MRI machines, dialysis machines, diagnostic equipment, and ultrasound devices. These advancements have significantly enhanced the diagnosis, treatment, and monitoring of various medical conditions, improving patient outcomes and overall healthcare delivery. Biomedical engineers also study the intricate biological processes within the human body, aiming to understand why it functions the way it does and how different biological systems operate. This knowledge has led to the development of innovative technologies such as wearable sensors and pacemakers. These devices offer patients comfort while allowing remote and real-time monitoring of their health conditions. By leveraging biological insights, biomedical engineers have made significant strides in providing personalized and efficient healthcare solutions. Biomedical engineering has transformed and enhanced healthcare services in numerous ways. The field's innovations, ranging from groundbreaking inventions to new medicines, vital tools and devices, and technologies that monitor and support biological processes, have revolutionized the healthcare landscape. By combining engineering principles with medical knowledge, biomedical engineers have unlocked the potential to improve health outcomes, enhance patient experiences, and ultimately make a positive impact on society as a whole.

### ***Advancements within the domain of medical science***

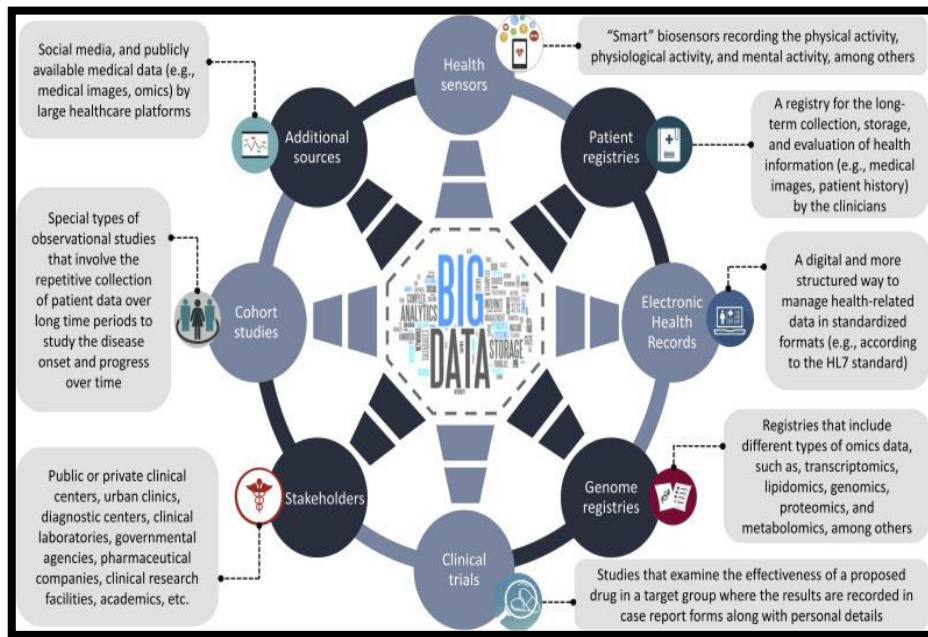
The field of biomedical engineering is at the forefront of transformative medical technology advancements that have the potential to revolutionize healthcare. With a focus on incorporating innovative tools and techniques, biomedical engineers are driving significant changes in how we receive treatment and improving the overall

quality of patient care. One of the most exciting developments in biomedical engineering is the rise of robotics in surgery. Surgical robots offer various advantages, such as increased precision, reduced natural shakes, and the ability to perform minimally invasive procedures. These advancements lead to smaller incisions, faster recovery times, and a lower risk of infection. Biomedical engineers are also exploring the possibility of telesurgeries, where surgeons can control robots remotely to perform surgeries, enabling expert medical care in remote areas. Tissue engineering is another area where biomedical engineering is making remarkable strides. The advent of 3D printing has opened doors for creating functional organs and tissues that can potentially be transplanted into patients. Biomedical engineers are also utilizing 3D printing to develop tissue models for studying diseases, treatment responses, and the physiological impacts of various factors. For example, researchers have successfully printed 3D models of blood vessels, allowed in-depth analysis of healthy and diseased tissues and enhanced our understanding of the cardiovascular system. The integration of artificial intelligence (AI) and virtual reality (VR) into biomedical engineering has paved the way for groundbreaking applications in medicine.

AI algorithms can assist in the identification and analysis of medical images, aiding in the diagnosis and treatment of diseases. VR technology is being utilized to create realistic simulations of patient anatomy, enabling doctors to practice complex procedures before performing them on real patients. Additionally, VR is being used as a training tool for medical professionals, providing immersive experiences and enhancing their skills in communication, empathy, and patient care. The Big Data types are illustrated in Figure 3 with Figure 4 providing the visualization of data science in terms of medical data. These advances in biomedical engineering are not limited to research labs or academic settings. Many of these technologies are already finding their way into medical facilities, benefiting patients directly. From improved X-ray technology to robotic-assisted surgeries and the training of medical professionals using VR, biomedical engineering is reshaping healthcare and paving the way for longer, healthier lives.



**Figure 3.** Types of big data in medical science.



**Figure 4.** Data science in terms of medical data.

Biomedical Engineering (BME) is driving transformative advancements in medical technology. The incorporation of robotics, tissue engineering, AI, and VR is revolutionizing the way we approach diagnosis, treatment, and training in healthcare. With the potential for minimally invasive procedures, enhanced imaging capabilities, and improved patient outcomes, the impact of biomedical engineering is set to positively impact the lives of individuals across the globe.

### ***Recent innovations and advances within BME***

Recent trends in biomedical engineering are revolutionizing healthcare and paving the way for advancements in prosthetics, surgical devices, diagnostics, imaging methods, and more. The field is rapidly growing, incorporating innovative technologies and interdisciplinary approaches to improve medical outcomes and enhance patient care. One significant trend is the proliferation of wearable devices and implantable technologies. Wearable health devices and implantable, such as fitness trackers and cardiac monitors, provide real-time data that enable early detection of symptoms, personalized treatment, and remote monitoring. These technologies have the potential to improve diagnosis, reduce healthcare costs, and optimize patient care. Nanorobotics is another emerging trend in biomedical engineering. By manipulating biological matter at the molecular level, nanorobots hold promise in fighting diseases. These microscopic robots can be programmed to perform functions like searching for pathogens or monitoring vital signs. Recent breakthroughs in nanotechnology have shown potential in shrinking tumors and offering less harmful alternatives to treatments like chemotherapy. Brain-computer interfaces (BCIs) are devices that allow signals from the brain to direct external activity, offering hope to individuals with motor disabilities. BCIs measure brain electrical activity and enable users to control external devices like prosthetic limbs. While ethical questions surrounding BCIs exist, ongoing research is improving accuracy and expanding their applications. BCIs have the potential to

augment human cognition and perception, blurring the line between humans and technology.

3D bioprinting is an emerging technology that combines cells, growth factors, and biomaterials to create tissue-like structures. Scientists have already achieved significant milestones, such as 3D-printing a human-sized heart using human cells. The potential of 3D bioprinting extends to printing artificial skin cells for burn victims and eventually creating replacement organs. This technology has the potential to revolutionize organ transplantation and improve treatment options for various medical conditions. Biomedical engineering is at the forefront of healthcare advancements, integrating technology, biology, and engineering to improve medical outcomes and enhance patient well-being. Wearable devices, nanorobotics, brain-computer interfaces, and 3D bioprinting represent some of the exciting recent trends that are transforming the medical landscape and offering new possibilities for the future of healthcare.

### ***Important and significant trends in BME***

Biomedical engineering has led to numerous inventions and innovations that have significantly impacted the field of healthcare. Prosthetics, including artificial limbs and dentures, have greatly improved the quality of life for individuals with missing or impaired body parts. Bionic contact lenses have enabled enhanced vision capabilities, while bionic exoskeletons have provided mobility assistance for individuals with disabilities. Robotic and laser instruments have revolutionized surgical procedures, making them more precise and less invasive. Implantable medical and drug delivery devices have facilitated targeted treatments and improved patient outcomes. Medical imaging technologies like X-ray and MRI machines have allowed for accurate diagnoses and monitoring of conditions. Radiation therapy has become a powerful tool in cancer treatment, while transcutaneous electrical nerve stimulation (TENS) devices have provided pain relief for various conditions. Nanomaterials have opened up new possibilities in drug delivery and tissue engineering, and bioprinting has allowed for the creation of functional human tissue and organs. The advent of genome editing technologies has paved the way for precise modifications in genetic material, enabling potential treatments for genetic diseases. In addition to these specific inventions, there are several trends in biomedical engineering that are shaping the future of healthcare. Tissue engineering and bioprinting offer the potential for creating artificial tissues and organs, at the same time revolutionizing transplantation procedures. Organs-on-chips, microbubbles, and transdermal patches are emerging technologies that show promise in diagnostics and drug delivery. Wearable medical devices, such as fitness trackers and health monitors, provide real-time data for better disease management and preventive care. Surgical robotics and nanorobots are advancing surgical precision and capabilities. Medical virtual reality is being used for training, therapy, and surgical planning. Artificial intelligence is being integrated into medical imaging to improve diagnostic accuracy. Personalized medicine, which mainly tailor's treatments to an individual's genetic profile and lifestyle, is becoming more feasible with advancements in biomedical engineering.

The Internet of Medical Things (IoMT) is playing an increasingly important role in biomedical engineering. It encompasses the interconnectedness of medical devices and applications, allowing for real-time monitoring, diagnostics, and data analysis. IoMT enables personalized and remote healthcare delivery, enhancing patient outcomes and convenience. From wearable devices to imaging machines and smart beds, IoMT is

transforming the healthcare landscape and improving the overall patient experience. Not only that, biomedical engineering has also led to a wide range of inventions and innovations that have transformed healthcare. From prosthetics to imaging technologies, these advancements have improved patient care, enabled new treatment modalities, and enhanced quality of life. Emerging trends such as tissue engineering, bioprinting, wearable devices, surgical robotics, and IoMT are driving further advancements in the field, promising a future of personalized and technologically advanced healthcare.

### ***Deep learning (DL) and Machine Learning (ML) in BME***

Machine learning has become an essential tool in biomedical research due to its ability to address complex datasets and provide valuable insights. One common use of machine learning is for making predictions based on measurable data. For example, in psychiatric medicine, machine learning has been used to predict mood based on smartphone recordings of everyday behaviors. In neuroscience, machine learning techniques have been employed to decode neural activity and infer intentions from brain measurements, enabling advancements in prosthetics and interactive devices. Machine learning also serves as a benchmark for evaluating human-generated models, helping to identify missing principles or misguided approaches. Additionally, machine learning aids in understanding complex systems by determining nonlinear relationships between variables and identifying shared information between components of a system. As datasets in biomedical research continue to grow in complexity, machine learning becomes indispensable. Humans are limited in their ability to comprehend and model complex datasets, often missing important patterns and structures. Machine learning techniques excel in capturing complex relationships and can handle large, multifaceted datasets. Moreover, machine learning addresses challenges posed by nonlinearity and recurrence, which are prevalent in biological systems. By embracing the complexity inherent in biomedical data, machine learning provides better fits and more accurate predictions compared to simpler models. Machine learning also supports the collection of a large number of variables, as it can improve predictions even when the contributions of individual variables are unclear.

The application of machine learning in neuroscience serves as a compelling example of its capabilities. In neural decoding, machine learning techniques have outperformed traditional linear approaches in predicting intentions based on brain activity. Neural network-based methods, along with ensemble methods that combine multiple techniques, have achieved remarkable results. Machine learning also challenges the common practice of using simple models in neural encoding, where signals from neurons are analyzed in relation to external variables. Machine learning algorithms, such as neural networks and extreme gradient-boosted trees, have surpassed generalized linear models in capturing the complex relationships between neural activity and external variables. By setting benchmarks and providing more accurate descriptions of neural computations, machine learning enhances our understanding of the human brain. While machine learning techniques may seem complex, their implementation has become increasingly accessible. With the availability of user-friendly software packages and automated machine learning tools, biomedical scientists can easily apply machine learning to their research without extensive knowledge of specific algorithms. This empowers researchers to focus on formulating scientific questions and interpreting the results generated by machine learning models.

Machine learning has become a necessity in biomedical research due to its ability to address complex datasets, make accurate predictions, benchmark human-generated models, and enhance understanding. From predicting mood based on smartphone data to decoding neural activity and modeling complex biological systems, machine learning offers valuable insights and advancements in various biomedical disciplines. As datasets continue to grow, machine learning's capacity to handle complexity and capture nonlinear relationships will be crucial in furthering our understanding of biological processes and improving healthcare outcomes

### ***AI, DL, ML integrations within functional genomics***

Machine learning has revolutionized the field of biology and bioinformatics, enabling researchers to analyze complex biological data, make predictions, and gain deeper insights into various biological processes. In genomics, machine learning techniques have been applied to regulatory genomics, structural genomics, and functional genomics. They have helped predict gene expression, classify protein structures, and identify gene functions and interactions. Machine learning methods combined with natural language processing have also facilitated the analysis of large genomics-related datasets, aiding in relation extraction and named entity recognition. One of the significant applications of machine learning in genomics is genome sequencing. Next-generation sequencing techniques, empowered by machine learning algorithms, have drastically reduced the time and cost required to sequence genomes. Machine learning has also played a crucial role in gene editing processes, such as CRISPR, by assisting in the selection of the correct DNA sequence for editing. In proteomics, machine learning has contributed to the analysis of protein components, their interactions, and their roles within organisms. Mass spectrometry-enabled proteomics has been enhanced by machine learning algorithms, which help identify proteins from mass spectral peaks and improve the accuracy of protein recognition.

These advancements have facilitated the diagnosis of diseases and expanded our understanding of protein patterns. Microarrays, used to detect gene expressions, have benefited from machine learning techniques, particularly in gene classification and clustering. Machine learning has made it easier to identify significant interactions in complex experiments and analyze large-scale microarray datasets. It has also enabled the prediction of future gene stages and the discovery of relationships between genes and diseases. Text mining, powered by machine learning and natural language processing, has been valuable in extracting and analyzing information from biological publications. This technology enables researchers to process and analyze large volumes of documents, aiding in large-scale protein and molecule interaction analysis, translation of content into different languages, searching for drug targets, and automatic annotation of gene and protein functions. In systems biology, machine learning has become instrumental in modeling complex biological interactions and behaviors. It helps capture the interactions between biological components and simulate the behavior of biological systems. Machine learning techniques, such as probabilistic graphical models and genetic algorithms, have been used to model genetic networks and regulatory structures. They have also facilitated the identification of relationships between phenotypes and genotypes, shedding light on the critical genetic composition of organisms. Machine learning has transformed the field of biology and bioinformatics by providing powerful tools to analyze and interpret complex biological data, make accurate predictions, and enhance our understanding of biological processes. It has accelerated research in

genomics, proteomics, microarrays, text mining, and systems biology, opening up a whole new avenue for discoveries and advancements in the field of biology.

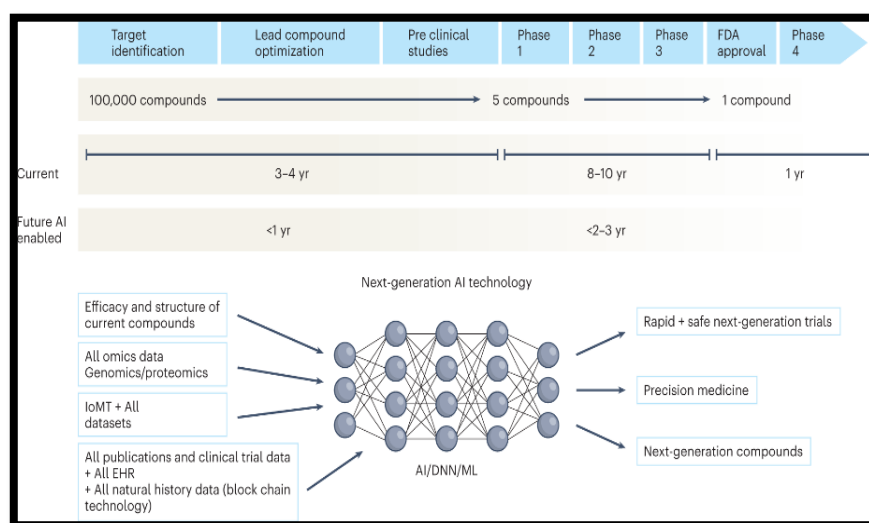
### ***Functional genomics: The healthcare perspective***

Machine learning and artificial intelligence (AI) have made significant contributions to the healthcare industry, enhancing patient care and improving quality of life. These technologies are being used in various applications to transform healthcare delivery. One important area is drug discovery and manufacturing, where machine learning is used in the early stages to assist in finding alternative options for multifactorial disease therapy. Precision medicine and next-generation sequencing techniques have proven valuable in this process. Medical imaging and diagnosis have also benefited greatly from machine learning and AI. Computer vision technologies, powered by deep learning and machine learning algorithms, enable advanced analysis of medical images. This technology is used in applications such as tumor detection, radiology interpretation, and quantitative analysis of 3D medical images. Projects like Microsoft's Inner Eye are utilizing machine learning to improve medical image analysis and diagnosis. Personalized medicine is another promising application of machine learning in healthcare. By leveraging predictive analytics on patient data, machine learning algorithms can assist in generating personalized treatment options. This approach goes beyond traditional diagnostic methods and takes into account individual patient characteristics, health history, and genetic information. Machine learning algorithms can analyze large datasets and identify patterns that can guide personalized treatment decisions. Machine learning is also being used in stroke diagnosis and treatment. Pattern recognition algorithms help in diagnosing, treating, and predicting complications in neurological diseases, including stroke. Algorithms such as Support Vector Machines (SVM) and 3D Convolutional Neural Network (CNN) are used to predict motor deficits in stroke patients, aiding in personalized rehabilitation planning.

In the field of biology and bioinformatics, machine learning tools have revolutionized data analysis and modeling. Deep Variant is a deep-learning tool used for genome data mining. It accurately predicts common genetic variations and provides scalable, cloud-based solutions for complex genomics datasets. Atom wise algorithms enable the study of the 3D structure of proteins and other molecules with atomic precision, facilitating drug discovery. Cell Profiler, a software powered by machine learning methods, allows for the quantitative measurement of individual cell features from microscopy images, enabling a very high-throughput analysis of biological samples. Machine learning, particularly through deep learning algorithms, extracts meaningful information from large datasets such as genomes or images, and builds models based on the extracted features. These models can then be used for analysis and prediction on other biological datasets. The application of machine learning in biology and bioinformatics has accelerated research, enabling the discovery of new patterns and relationships in complex biological systems. Machine learning is transforming healthcare and biology by enabling more accurate diagnosis, personalized treatment, and advanced data analysis. These technologies have the potential to revolutionize the field, leading to better patient outcomes and advancements in biological research.

### ***AI, DL, ML perspectives within medical healthcare***

Artificial intelligence (AI) has revolutionized the healthcare industry by improving patient care and outcomes. AI in healthcare has the potential to transform the way we diagnose diseases, develop treatments, and prevent illnesses. The use of AI technology, such as machine learning and natural language processing, has enabled medical professionals to make more accurate diagnoses, personalize treatments, and streamline clinical processes. Machine learning, one of the most common AI techniques in healthcare, has facilitated medical diagnosis and treatment by processing large amounts of clinical data, identifying patterns, and making predictions with higher accuracy. It has been used for precision medicine, predicting treatment success based on individual patient characteristics, and detecting correlations and changes in health data that may indicate health risks. Deep learning, a subset of machine learning, has also been applied to tasks such as speech recognition and natural language processing, aiding in medical record analysis and clinical decision-making. To better understand AI enabled mechanics in terms of healthcare Figure 5 gives a visual representation of the matter. Natural language processing (NLP) is another AI technology transforming healthcare. NLP enables computers to interpret and use human language, allowing for improved diagnosis and accuracy, personalized treatment recommendations, and streamlined clinical processes. By extracting valuable information from medical records and health data, NLP helps healthcare professionals make informed decisions and manage complex data more efficiently.

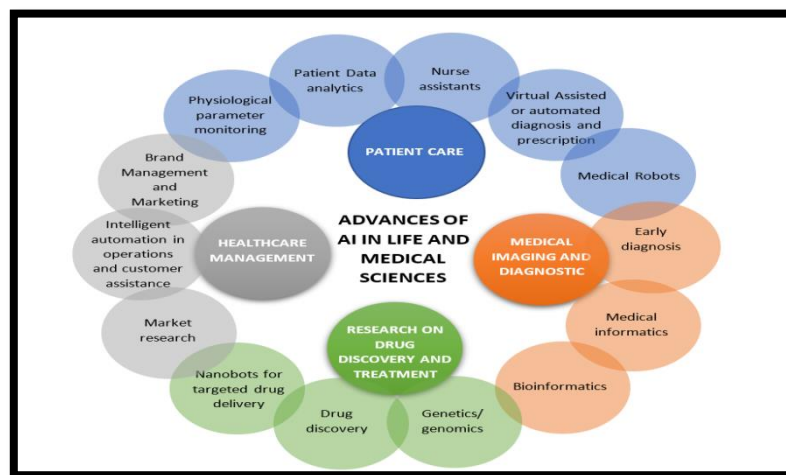


**Figure 5.** AI enable healthcare visualization.

Rule-based expert systems, although less prevalent today, have played a role in clinical decision support by providing sets of rules for specific knowledge areas. However, machine learning approaches are gradually replacing rule-based systems, offering more flexibility and accuracy in healthcare analytics and decision-making. AI within healthcare has diverse applications, including diagnosis and treatment, administrative tasks, and data analysis. By automating administrative processes, AI reduces human error, saves time, and allows medical professionals to focus on patient care. Challenges associated with AI adoption in healthcare include data privacy and security, patient safety and accuracy, integration with existing IT systems, physician acceptance and trust, and compliance with regulations. Addressing these challenges is

crucial to ensure ethical and responsible use of AI in healthcare. Looking forward, AI in healthcare holds tremendous potential for further innovation and advancement. The use of AI-powered tools and algorithms can enable faster disease detection, personalized treatments, and automation of processes such as drug discovery and diagnostics. The future of AI in healthcare promises improved patient outcomes, increased safety, and reduced costs. However, the successful adoption of AI in healthcare relies on overcoming challenges and ensuring collaboration between AI technologies and medical professionals. Moreover, AI has transformed healthcare by enhancing diagnosis accuracy, personalizing treatments, streamlining processes, and improving patient care. As AI continues to advance, its impact on healthcare is expected to grow, leading to further advancements, better health outcomes, and improved patient experiences.

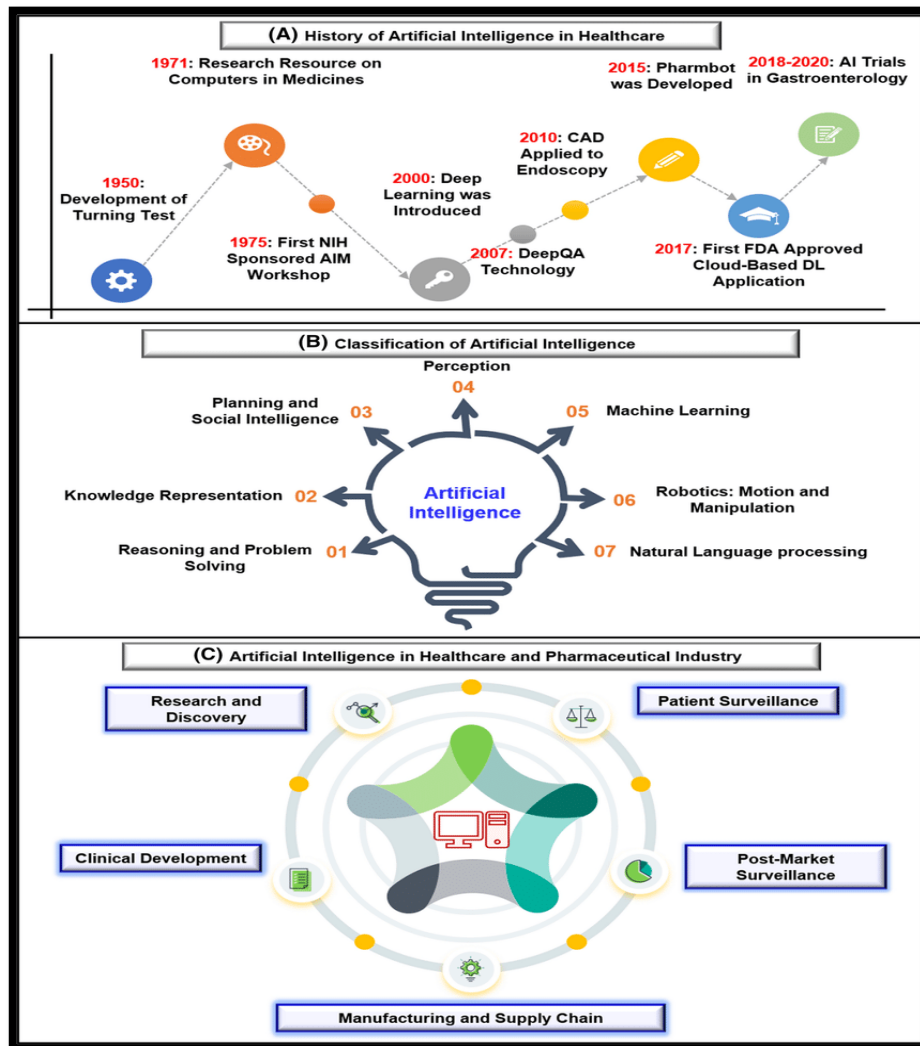
Artificial intelligence (AI) is making significant strides in various clinical applications, revolutionizing healthcare practices. In the field of cardiovascular medicine, AI algorithms are being developed to aid in diagnosing and risk stratifying patients with conditions such as coronary artery disease. Wearable devices and internet-based technologies are also being used to monitor cardiac data, enabling early detection of cardiac events outside of the hospital. AI has shown promise in dermatology for diagnosing skin cancer and classifying various skin diseases. It has achieved high accuracy levels in skin cancer detection, surpassing human dermatologists in some cases. Gastroenterology is another area where AI can enhance endoscopic procedures, allowing for faster disease identification and visualization of blind spots. Infectious diseases are being tackled with the help of AI, with applications ranging from predicting treatment outcomes and identifying antimicrobial resistance to diagnosing diseases such as malaria, meningitis, and tuberculosis. Musculoskeletal applications of AI include identifying causes of knee pain, particularly in underserved populations, to improve diagnosis and management. Oncology has seen significant progress in using AI for cancer diagnosis, risk stratification, molecular characterization of tumors, and drug discovery. AI algorithms have shown promise in detecting breast cancer and prostate cancer with high accuracy rates. To better understand the significance concerning the matter Figure 6 representation provides a global view of advances of AI in life and medical sciences.



*Figure 6. AI advances in life and medical sciences.*

Ophthalmology benefits from AI applications for screening eye diseases, with FDA approval granted for the use of AI algorithms in diagnosing diabetic retinopathy. AI can assist pathologists in analyzing digital pathology images, aiding in the diagnosis of diseases such as breast cancer, gastric cancer, and colorectal cancer. Primary care is also utilizing AI for decision support, predictive modeling, and business analytics to improve patient care and treatment outcomes. In psychiatry, AI is being explored for predictive modeling of diagnoses and treatment outcomes, as well as the development of chat-bot therapy for conditions like anxiety and depression. Radiology is an area where AI is making significant strides, particularly in interpreting medical imaging scans. Deep learning models have demonstrated accuracy comparable to that of human experts in identifying diseases through CT and MR imaging. AI also offers non-interpretive benefits to radiologists, such as reducing noise in images, enhancing image quality, and automatically assessing image quality. Disease diagnosis and classification benefit from AI techniques, including artificial neural networks and Bayesian networks. AI-assisted diagnosis based on electronic health records (EHRs) is helping physicians make more accurate diagnoses and treatment decisions by leveraging mass data and identifying similar cases. Telemedicine is another area where AI is gaining traction, enabling remote patient monitoring and providing real-time alerts to physicians based on sensor data. EHRs are being analyzed and interpreted using natural language processing, making reports more concise and standardized.

AI algorithms are also used to predict disease risk based on patient records and family history. Drug interactions pose a threat to patients taking multiple medications, and AI is being utilized to identify potential drug-drug interactions by analyzing medical literature and user-generated content such as adverse event reports. To provide an overall visualization on the aspect of the matter concerning the medical domain Figure 7 provides the history of AI in healthcare. The healthcare industry is witnessing the implementation of artificial intelligence (AI) through the collaboration and mergers of large health companies, allowing for greater accessibility to health data. These partnerships provide a foundation for the development and integration of AI algorithms. Many companies are exploring the incorporation of big data in healthcare, focusing on data assessment, storage, management, and analysis technologies. Several prominent companies have contributed to the advancement of AI algorithms in healthcare. IBM's Watson Oncology is being developed in partnership with leading cancer centers to assist in personalized cancer treatment. Microsoft's Hanover project analyzes medical research to predict highly effective cancer drug treatments. Google's DeepMind platform is being used by the UK National Health Service for risk detection and cancer tissue analysis. Tencent is working on various medical systems and services, including AI-powered diagnostic imaging and intelligent healthcare through their WeChat platform. Intel has invested in startups like Lumiata, which uses AI to identify at-risk patients and develop care options. Neuralink, founded by Elon Musk, has developed a next-generation neuroprosthetic that interfaces with neural pathways in the human brain.



*Figure 7. A history of AI in healthcare.*

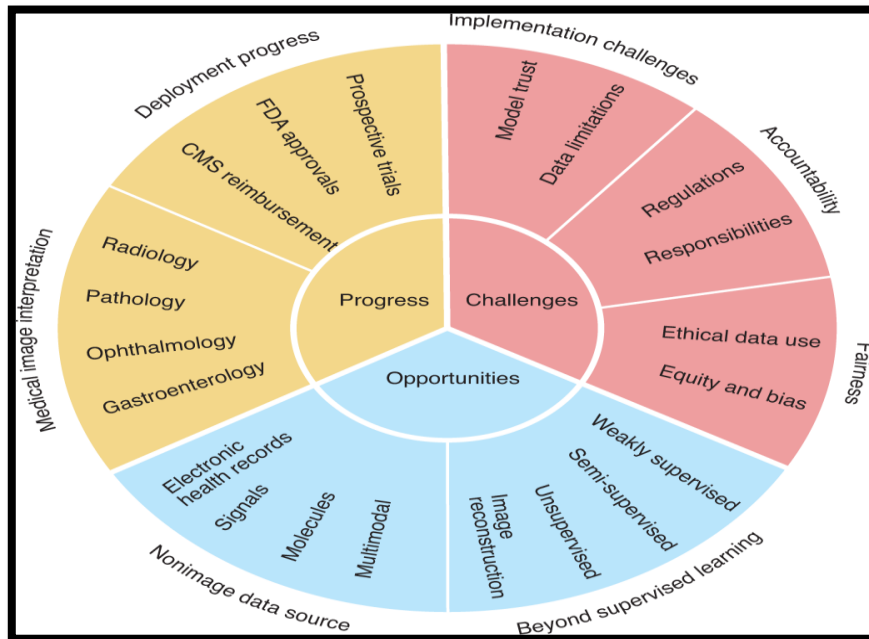
While AI holds great potential in these clinical applications, challenges remain. Validation of AI models against human performance is essential, as is addressing issues of bias, interpretability, and privacy. Further research and clinical trials are needed to assess the true clinical utility of AI in various healthcare settings. AI has the potential to revolutionize clinical practices, improve patient outcomes, and enhance the efficiency and accuracy of healthcare delivery. AI is also transforming healthcare delivery in developing nations by improving access to diagnosis and treatment. With the increasing capabilities of AI over the internet, machine learning algorithms can accurately diagnose life-threatening diseases in areas where healthcare resources are limited. AI enables a level of personalized care that is often lacking in developing countries. The regulatory landscape for AI in healthcare is evolving. Regulations such as the Health Insurance Portability and Accountability Act (HIPAA) and the European General Data Protection Regulation (GDPR) protect patient data and privacy. The U.S. FDA has published an Action Plan for the regulation of medical devices incorporating AI. The U.S. Department of Health and Human Services has issued guidance on the ethical use of AI, emphasizing principles such as respect for autonomy, beneficence, non-maleficence, and justice. Similar regulations and guidelines exist in other countries,

such as Denmark and the European Union, to ensure responsible data use and protect individual rights.

AI is revolutionizing the healthcare industry by improving clinical decision support systems, expanding access to care, and enhancing patient outcomes. Large companies are investing in AI research and development, and regulations are being developed to address ethical concerns and protect patient data. The implementation of AI in healthcare holds great promise for improving healthcare delivery, particularly in underserved areas and developing nations to a great extent.

**Discussions**

The future of AI in healthcare holds tremendous potential to transform the industry in various ways. One significant advantage of AI is its ability to analyze large volumes of data quickly and accurately. By leveraging machine learning algorithms, AI can identify patterns and predict outcomes based on extensive datasets, leading to improved diagnoses and treatment plans. Medical imaging is another area where AI can make a significant impact. AI algorithms can be trained to detect abnormalities in images such as X-rays, CT scans, and MRIs, accelerating diagnoses and reducing the risk of human error. Personalized medicine is another area where AI can excel. By analyzing a patient's medical history, genetic information, and lifestyle factors, AI can provide tailored treatment recommendations that meet each patient's unique needs. Remote patient monitoring is also a promising application of AI in healthcare. By continuously monitoring patients and detecting early warning signs of complications, AI can enable healthcare professionals to intervene before conditions worsen, resulting in better patient outcomes and reduced hospital readmissions. A summary of the research exploration results and findings are illustrated within Figure 8 and Figure 9 while Figure 10 and Figure 11 providing an experimental visualization design for future healthcare.



**Figure 8.** A visual representation of the findings from the research results 1.

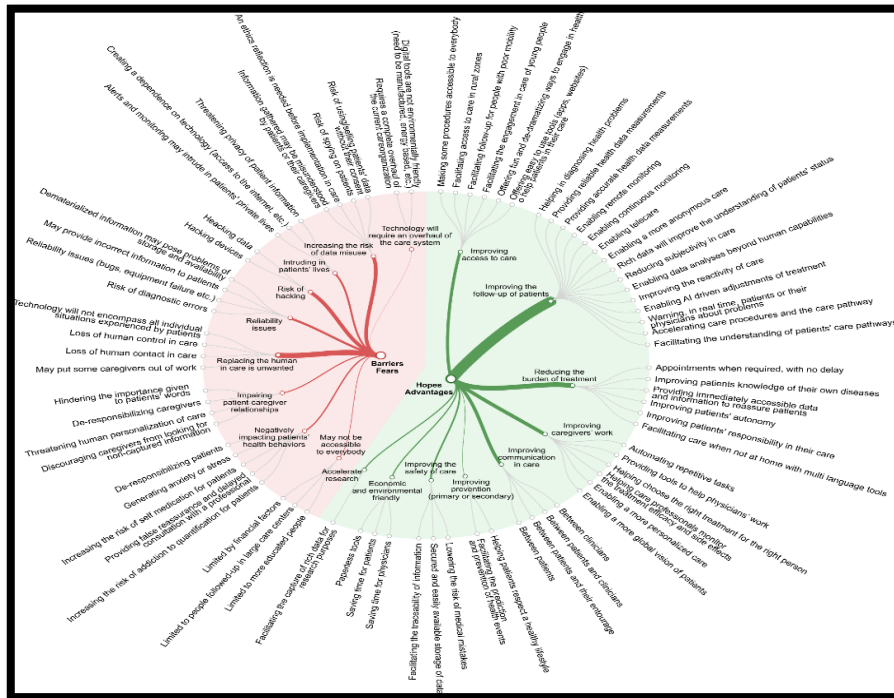
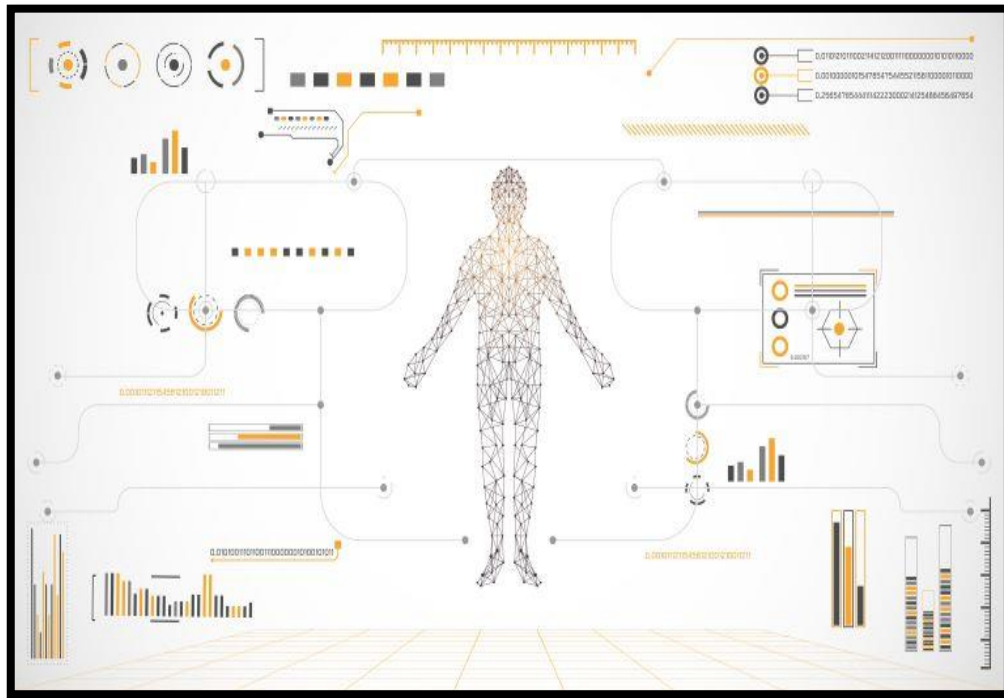


Figure 9. A visual representation of the findings from the research results 2.



Figure 10. A visualization of future healthcare (experimental) 1.



*Figure 11. A visualization of future healthcare (experimental) 2.*

Research in the field of AI and healthcare has been crucial in developing the technology we have today. It has led to breakthroughs in areas such as medical imaging, drug development, and personalized medicine. AI algorithms can analyze vast amounts of data, including patient records and clinical trials, to identify patterns and make accurate predictions, enhancing diagnoses and treatment plans. The development of natural language processing algorithms has enabled the analysis of unstructured data, such as doctor's notes and patient records, to extract vital information and trends, further improving medical decisions. Wearable devices are another outcome of AI research in healthcare. These devices can monitor a patient's health remotely, collecting data on vital signs and transmitting it to healthcare professionals in real-time. This facilitates early intervention and improves patient outcomes significantly. In response to all that, AI has the potential to revolutionize healthcare by providing faster and more accurate diagnoses, enhancing treatment plans, and improving patient care and safety. Ongoing research in the field of AI and healthcare will continue to push the boundaries, leading to further advancements and a healthier world. The future of AI in healthcare looks promising, and its applications are poised to make a significant positive impact on the industry.

## **Conclusion**

Accelerated Computing has completely changed the way how we humans view and visualize particulars to an overwhelming level of superiority. In spite of all the advancements and rapid development and deployment of data device peripherals and AI integration there is still a huge concern in the relation towards human health. The better the system the more complexify the scenario and outcome becomes. As a civilization, we are constantly evolving with time and the computing technicality continues to grow our interest to dive higher into the unknown. But we cannot ignore the matter when it

revolves around and concerns between life and death. Proper Ethics and Moral Integrity are very crucial for a context like human health. If not checked properly and without authentic guidelines and instructions even the greatest of systems can produce an unimaginable error. When that level of hierarchy concerns around health it is a matter of life and death and to beyond. The COVID-19 Pandemic was a prime example of how devastating the consequences can shape out to be and impact human lives to a scale of unimaginable heights.

In the context of today and in the near future and in the following years to come the whole world will go through a wide range of shift in terms of both engineering and medical science to a great degree and will change the way how humans deal with machinery and technicality to a great extent. True, remarkable and great innovations and extraordinary achievements will be applicable but in the midst of all the betterment we must not lose sight of what is truly needed and required in terms of health. The way the prospect is moving towards perhaps when at its peak even the most unorthodox matter and issue might rise in terms of human mortality and how there can a path beyond that line of scaling and a situation alternate can be made possible. So, there is a lot of matter and concern to consider from diversity of backgrounds. One thing must be understood above everything else; Every Human Being is Liable to Error and the author will finish this retrospect upon that and leave the rest to time and human civilization society.

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### **Conflict of interest**

There are no Conflict of Interest or any type of Competing Interests for this research.

### **REFERENCES**

- [1] Akhtar, Z.B. (2024): The design approach of an artificial intelligent (AI) medical system based on electronical health records (EHR) and priority segmentations. – The Journal of Engineering 10p.
- [2] Akhtar, Z.B. (2022): A Revolutionary Gaming Style in Motion. – IntechOpen 20p.
- [3] Akhtar, Z.B., Gupta, A.D. (2024a): Integrative Approaches for Advancing Organoid Engineering: From Mechanobiology to Personalized Therapeutics. – Journal of Applied Artificial Intelligence 5(1): 1-27.
- [4] Akhtar, Z.B., Gupta, A.D. (2024b): Advancements within Molecular Engineering for Regenerative Medicine and Biomedical Applications an Investigation Analysis towards A Computing Retrospective. – Journal of Electronics, Electromedical Engineering, and Medical Informatics 6(1): 54-72.
- [5] Akhtar, Z.B., Rozario, V.S. (2020): The Design Approach of an Artificial Human Brain in Digitized Formulation based on Machine Learning and Neural Mapping. – In 2020 International Conference for Emerging Technology (INCET), IEEE 7p.

- [6] Arnold, C.D., Gerlach, D., Stelzer, C., Boryń, Ł.M., Rath, M., Stark, A. (2013): Genome-wide quantitative enhancer activity maps identified by STARR-seq. – *Science* 339(6123): 1074-1077.
- [7] Bahl, M., Barzilay, R., Yedidia, A.B., Locascio, N.J., Yu, L., Lehman, C.D. (2018): High-risk breast lesions: a machine learning model to predict pathologic upgrade and reduce unnecessary surgical excision. – *Radiology* 286(3): 810-818.
- [8] Baxt, W.G. (1991): Use of an artificial neural network for the diagnosis of myocardial infarction. – *Annals of Internal Medicine* 115(11): 843-848.
- [9] Buchanan, B.G., Shortliffe, E.H. (1984): Rule based expert systems: the mycin experiments of the stanford heuristic programming project (the Addison-Wesley series in artificial intelligence). – Addison-Wesley Longman Publishing Co., Inc. 8p.
- [10] Chan, S., Reddy, V., Myers, B., Thibodeaux, Q., Brownstone, N., Liao, W. (2020): Machine learning in dermatology: current applications, opportunities, and limitations. – *Dermatology and Therapy* 10(3): 365-386.
- [11] Chen, W., Sun, Q., Chen, X., Xie, G., Wu, H., Xu, C. (2021): Deep learning methods for heart sounds classification: A systematic review. – *Entropy* 23(6): 18p.
- [12] Couvreur, P., Vauthier, C. (2006): Nanotechnology: intelligent design to treat complex disease. – *Pharmaceutical Research* 23(7): 1417-1450.
- [13] Cuello, J.C. (2005): 'Engineering to biology'and'biology to engineering': The bi-directional connection between engineering and biology in biological engineering design. – *Int J Engng Ed* 21: 1-7.
- [14] Curtis, A.S., Dalby, M., Gadegaard, N. (2006): Cell signaling arising from nanotopography: implications for nanomedical devices. – *Nanomedicine* 1(1): 67-72.
- [15] Dougherty, G. (2009): Digital image processing for medical applications. – Cambridge University Press 459p.
- [16] Duda, R.O., Shortliffe, E.H. (1983): Expert systems research. – *Science* 220(4594): 261-268.
- [17] Diss, G., Lehner, B. (2018): The genetic landscape of a physical interaction. – *Elife* 7: 31p.
- [18] Enderle, J., Bronzino, J. (2011): Introduction to biomedical engineering. – Academic Press 1141p.
- [19] Fields, S., Song, O.K. (1989): A novel genetic system to detect protein–protein interactions. – *Nature* 340(6230): 245-246.
- [20] Fiers, W., Contreras, R., Haegeman, G., Rogiers, R., Van De Voorde, A., Van Heuverswyn, H., Van Herreweghe, J., Volckaert, G., Ysebaert, M. (1978): Complete nucleotide sequence of SV40 DNA. – *Nature* 273(5658): 113-120.
- [21] Galas, D. (2015): Systems biology. – *The Encyclopedia Britannica* 16p.
- [22] Gilbert, L.A., Horlbeck, M.A., Adamson, B., Villalta, J.E., Chen, Y., Whitehead, E.H., Guimaraes, C., Panning, B., Ploegh, H.L., Bassik, M.C., Qi, L.S. (2014): Genome-scale CRISPR-mediated control of gene repression and activation. – *Cell* 159(3): 647-661.
- [23] Goyal, M.R. (2018): Scientific and Technical Terms in Bioengineering and Biological Engineering. – CRC Press 662p.
- [24] GTEx Consortium Lead analysts: Aguet François 1 Brown Andrew A. 2 3 4 Castel Stephane E. 5 6 Davis Joe R. 7 8 He Yuan 9 Jo Brian 10 Mohammadi Pejman 5 6 Park YoSon 11 Parsana Princy 12 Segrè Ayellet V. 1 Strober Benjamin J. 9 Zappala Zachary 7 8, NIH program management: Addington Anjene 15 Guan Ping 16 Koester Susan 15 Little A. Roger 17 Lockhart Nicole C. 18 Moore Helen M. 16 Rao Abhi 16 Struewing Jeffery P. 19 Volpi Simona 19, Pathology: Sobin Leslie 30 Barcus Mary E. 30 Branton Philip A. 16, NIH Common Fund Nierras Concepcion R. 137 and NIH/NCI Branton Philip A. 138 Carithers Latarsha J. 138 139 Guan Ping 138 Moore Helen M. 138 Rao Abhi 138 Vaught Jimmie B. (2017): Genetic effects on gene expression across human tissues. – *Nature* 550(7675): 204-213.

- [25] Graur, D., Zheng, Y., Price, N., Azevedo, R.B., Zufall, R.A., Elhaik, E. (2013): On the immortality of television sets: "function" in the human genome according to the evolution-free gospel of ENCODE. – *Genome Biology and Evolution* 5(3): 578-590.
- [26] Hart, T., Chandrashekhar, M., Aregger, M., Steinhart, Z., Brown, K.R., MacLeod, G., Mis, M., Zimmermann, M., Fradet-Turcotte, A., Sun, S., Mero, P. (2015): High-resolution CRISPR screens reveal fitness genes and genotype-specific cancer liabilities. – *Cell* 163(6): 1515-1526.
- [27] Infante, T., Cavaliere, C., Punzo, B., Grimaldi, V., Salvatore, M., Napoli, C. (2021): Radiogenomics and artificial intelligence approaches applied to cardiac computed tomography angiography and cardiac magnetic resonance for precision medicine in coronary heart disease: a systematic review. – *Circulation: Cardiovascular Imaging* 14(12): 1133-1146.
- [28] Jacobson, L.E., Olayan, M., Williams, J.M., Schultz, J.F., Wise, H.M., Singh, A., Saxe, J.M., Benjamin, R., Emery, M., Vilem, H., Kirby, D.F. (2019): Feasibility and safety of a novel electromagnetic device for small-bore feeding tube placement. – *Trauma Surgery & Acute Care Open* 4(1): 7p.
- [29] Jain, L. (2023): *Artificial Intelligence and Machine Learning for Healthcare*. – Springer Nature 231p.
- [30] Jha, A.K., DesRoches, C.M., Campbell, E.G., Donelan, K., Rao, S.R., Ferris, T.G., Shields, A., Rosenbaum, S., Blumenthal, D. (2009): Use of electronic health records in US hospitals. – *New England Journal of Medicine* 360(16): 1628-1638.
- [31] Johnson, A.T., Phillips, W.M. (1995): Philosophical foundations of biological engineering. – *Journal of Engineering Education* 84(4): 311-318.
- [32] Kassab, G.S. (2004): YC" Bert" Fung: The Father of Modern Biomechanics. – *Molecular & Cellular Biomechanics* 1(1): 5-22.
- [33] Koomey, J., Berard, S., Sanchez, M., Wong, H. (2010): Implications of historical trends in the electrical efficiency of computing. – *IEEE Annals of the History of Computing* 33(3): 46-54.
- [34] Kwasniewski, J.C., Fiore, C., Chaudhari, H.G., Cohen, B.A. (2014): High-throughput functional testing of ENCODE segmentation predictions. – *Genome Research* 24(10): 1595-1602.
- [35] Li, Y., Shi, W., Wasserman, W.W. (2018): Genome-wide prediction of cis-regulatory regions using supervised deep learning methods. – *BMC Bioinformatics* 19: 1-14.
- [36] Mardis, E.R. (2008): Next-generation DNA sequencing methods. – *Annu. Rev. Genomics Hum. Genet.* 9: 387-402.
- [37] Miller, R.A. (1994): Medical diagnostic decision support systems-past, present, and future: a threaded bibliography and brief commentary. – *Journal of the American Medical Informatics Association* 1(1): 8-27.
- [38] Nirenberg, M., Leder, P., Bernfield, M., Brimacombe, R., Trupin, J., Rottman, F., O'neal, C. (1965): RNA codewords and protein synthesis, VII. On the general nature of the RNA code – *Proceedings of the National Academy of Sciences* 53(5): 1161-1168.
- [39] Pasotti, L., Zucca, S. (2014): Advances and computational tools towards predictable design in biological engineering. – *Computational and Mathematical Methods in Medicine* 17p.
- [40] Power, B. (2015): Artificial intelligence is almost ready for business. – *Harvard Business Review* 8p.
- [41] PR Newswire Web Portal (2020): COVID-19 Pandemic Impact: Global R&D Spend For AI in Healthcare and Pharmaceuticals Will Increase US\$1.5 Billion By 2025. – PR Newswire Web Portal 3p.
- [42] Roesler, H. (1987): The history of some fundamental concepts in bone biomechanics. – *Journal of Biomechanics* 20(11-12): 1025-1034.
- [43] Ryerson University (2011): Ryerson Biomedical Engineering Students Invent Brain-Controlled Prosthetic Arm. – Ryerson University Web Portal 3p.

- [44] Sotirakos, S., Fouda, B., Mohamed Razif, N.A., Cribben, N., Mulhall, C., O'Byrne, A., Moran, B., Connolly, R. (2021): Harnessing artificial intelligence in cardiac rehabilitation, a systematic review. – *Future Cardiology* 18(2): 154-164.
- [45] Subramanian, A., Tamayo, P., Mootha, V.K., Mukherjee, S., Ebert, B.L., Gillette, M.A., Paulovich, A., Pomeroy, S.L., Golub, T.R., Lander, E.S., Mesirov, J.P. (2005): Gene set enrichment analysis: a knowledge-based approach for interpreting genome-wide expression profiles. – *Proceedings of the National Academy of Sciences* 102(43): 15545-15550.
- [46] Vincent, J.F., Bogatyreva, O.A., Bogatyrev, N.R., Bowyer, A., Pahl, A.K. (2006): Biomimetics: its practice and theory. – *Journal of the Royal Society Interface* 3(9): 471-482.
- [47] Wang, H., Mayhew, D., Chen, X., Johnston, M., Mitra, R.D. (2011): Calling Cards enable multiplexed identification of the genomic targets of DNA-binding proteins. – *Genome Research* 21(5): 748-755.
- [48] Wang, H., Zu, Q., Chen, J., Yang, Z., Ahmed, M.A. (2021): Application of artificial intelligence in acute coronary syndrome: a brief literature review. – *Advances in Therapy* 9p.
- [49] World Health Organization (WHO) (2003): *Medical Device Regulations: Global overview and guiding principles*. – World Health Organization (WHO) 43p.