IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Unlocking The Potential Of Artificial Intelligence (AI)In Biotechnology: A Comprehensive Review

[1]Vaisakh. R, [2]Snigdha Sanal, [3]Theertha. K, [4]Evelin Rose. P, [5]Meera. S, [6]Ramya. K,

[7]Suja. G, [8]Nithya Devi. M, [9]VinothKumar. T

[1,2,3,4]M.Sc., Biotechnology students, [5]Research Scholar, [6,7,8]Assistant Professor, [9]Associate Professor and Director

[1-7]Department of Biotechnology, [8]Department of Biochemistry, [9]School of Biological Sciences

[1-9] CMS College of Science and Commerce, Coimbatore, India.

ABSTRACT

Artificial intelligence (AI) is looming as a technological concept and a requisite module, that can't be evaded. Such an emerging and potential technology provides an unavoidable reason to make a detailed review of its applications and challenges. AI is revolutionizing the field of Biotechnology by enhancing accuracy and efficiency by handling crucial sets of duties in diversified domains. This synergistic approach has become a great real-time problem solver over various issues. Unless providing accurate solutions, the process happens in a less competitive time, which, by humans, would be highly time-consuming and labour-intensive. The adoption of AI in biotechnology also faces major challenges over ethical and regulatory framework. Reviewing these challenges is essential for obtaining the ultimate potential innovation in the field. This review would be a promising one for the required basic information about Artificial Intelligence amalgamated with Biotechnology, which might be helpful for anyone who seeks content over the upcoming advancements.

***Index Terms* –** Artificial intelligence, Biotechnology, Machine Learning, Applications.

INTRODUCTION

Artificial Intelligence's (AI) inception by John McCarthy in 1956, various definitions have been provided. The rational approach defines AI as a system that uses computational programming to automate intelligent behaviour or develop intelligence over time and produces logical outputs to carry out specific tasks with little assistance from humans. With significant economic and societal implications, this discipline focuses on computer science and mathematics aspects of statistical modelling. Its goal is to develop technological systems capable of solving problems and carrying out tasks or obligations that are normally performed by the human mind [1]. AI systems often consume large amounts of labelled training data, which they then use to discover correlations and patterns and forecast future states. AI provides massive computing capacity, as well as a slew of new biological tools and methods. The current analysis will look at how AI applications are utilized to solve existing biotechnological challenges, how they aid in high-throughput requirements and data processing, and how new breakthroughs in AI technology offer up new possibilities for future. AI refers to a system's ability to effectively read outside data, learn from it, and use those insights to achieve specific actions and goals through adaptable change [2]. Machine learning, a subset of artificial intelligence (AI) that is primarily concerned with pattern recognition, describes techniques that allow computers to learn without being explicitly taught to do so, which greatly benefits in problem solving. The a fore mentioned approach has enabled rapid advances in the field of AI. Problem-solving, particularly in artificial intelligence, can be defined as the methodical investigation of a number of different courses of action in order to arrive at a preset target or solution. Sustainability's multidisciplinary character enables it to address a wide range of issues, such as clean technologies, food safety, sustainable agriculture, the environment, climate change, and green economy [3]. From a biological standpoint, the AI approach allows individuals to arrange information that is currently on the market in a disaggregated form, converting data into decisions while only considering tools that are useful in making decision-making processes easier. Big language models, such as ChatGPT, can answer queries and assertions in human language more readily and fluently, resulting in better decision-making. In this editorial, we discussed AI and how it operates efficiently [4]. The significance of it in the field of biotechnology is then examined, as well as the obstacles faced that should be considered in order to further future study, before a brief conclusion is reached.

1. A PRIMER ON AI

The notion of Artificial Intelligence (AI) is not a new one; it has been around for more than half a century. The introduction of neural networks in the 1980s and 1990s helped to popularize AI [5]. Most of what is referred to as Al, especially by the general public, is actually machine learning (ML). ML combines concepts and methods from statistics and computer science to process data, make predictions, and aid in decision making. This nomenclature shift from ML to Al has also been aided by the amazing advancements of Deep Learning (DL), a subfield of ML, when used in many domains, particularly image and speech recognition. These discoveries have resulted in a straightforward and exciting parallelism between artificial neural networks, which are at the heart of deep learning applications, and human brain networks [6]. Deep learning is a machine learning technique in which models are developed using artificial neural networks with numerous layers (often up to 1,000). Deep learning has produced substantial advances in a variety of non-health and health-related applications involving computer vision and natural language processing [5]. The term AI is widely used to convey how a machine replicates cognitive processes associated with the human brain during learning and problem solving [7]. Such attempts had limited success until recent years, when effective Al applications have permeated many facets of our daily lives. AI systems offer much greater transformation in the future: improved medical diagnosis, new illness remedies, scientific discoveries, predicting financial markets and geopolitical trends, and recognizing useful patterns in a wide range of data [8]. Integrating AI and robotics into healthcare is a revolutionary finding that has enormous promise for improving patient care, diagnostics, and treatment options [9]. They may increase speed and power while replacing numerous human duties. The Large Language Models (LLMs) can boost productivity, automate repetitive and enhance knowledge in low- and middle-income nations [10]. AI is a fascinating technologically advanced system that offers limitless opportunities in terms of applications. Future AI generations are expected to inspire new types of brain-inspired circuits and architectures capable of generating data-driven decisions faster and more precisely than humans [11]. These days, biological and chemical scientists widely use AI algorithms in the drug design and discovery process. Computational modelling based on AI and ML concepts is an excellent tool for identifying and validating chemical compounds, identifying targets, synthesizing peptides, and other applications in agriculture and healthcare [7].

2. PIONEERING AI SOLUTIONS IN BIOTECHNOLOGY

2.1 AI MEETS AGRICULTURE

The labour supply for production, the decreased transportation of agricultural products, and the hazards connected with agricultural markets are only a few of the disruptions that the agriculture sector has experienced. As a result, modern applications of artificial intelligence (AI) systems and solutions will be found in the fields of agriculture and sustainable agricultural methods.[12]

Climate change, population growth, and shrinking arable land have all increased the need for more accurate, high-throughput methods that can help create crop cultivars more quickly, accurately, and precisely. In this context, the recently developed field of artificial intelligence has been proposed to have exceptional promise for aiding in the inbreeding of climate-resilient smart crops. Artificial intelligence (AI) aims to use technology to mimic some aspects of human intelligence [11]. The breeding industry’s growing interest in AI is a result of technological maturity, or the capacity to quickly analyse vast volumes of data and uncover surprising connections. From a breeding perspective, the AI approach enables people to organize data that is generally already on the market in a disaggregated form, turning data into breeding decisions and only taking into account those tools that are helpful to speed up crop breeding decision-making processes.

The primary focus of using AI in breeding is that it ensures ongoing farm monitoring, which enhances the breeder's job [13]. In fact, breeders may spend less time in their buildings and more time on higher-value tasks as a result of farm automation and data generalization. Climate-resilient Biotech crops that can better endure heat, drought, and flooding are one example of an integrated set of tools that farmers can use [114]. AI significantly reduces the time required for data processing and identification [15].

High-throughput genomics and phenomics to improved breeding are two examples of how AI technology has sped up the process of creating new plant types. The application of machine learning (ML) techniques in marker-assisted selection, genomic prediction, and genomic selection has grown. Hundreds of millions of dollars have already been spent by numerous agricultural corporations, like Monsanto and John Deere, to create systems that can use vast amounts of data on weather, seed variety, and soil type to assist farmers in cutting expenses and increasing yields [16]. In order to better understand how plants behave in a range of environmental conditions, plant breeders are creating systems. In the near future, AI has the ability to revolutionize agriculture and ensure global food security.

International cooperation is necessary to address the issues of global food security brought on by crop failures caused by drought. The intricate interactions among heat, drought, and associated stressors highlight the variety of issues confronting agricultural systems around the world, necessitating in-depth study and flexible approaches. ML and DL techniques have become essential resources for researching and managing plant stress in recent years. Large data sets may be analyzed using these methods, which shed light on how plants react to environmental stress. Breeding efforts to create stress-resistant crops can benefit from the use of machine learning algorithms, which can detect genetic markers linked to stress tolerance or susceptibility. Predicting stress outcomes based on environmental parameters is one of the main uses of machine learning and deep learning in plant stress research. ML models can forecast how plants will react to stimuli by examining variables including light intensity, temperature variations, humidity, and soil moisture levels. This allows for early symptom diagnosis and prompt interventions [17].

Additionally, AI will be iteratively learnt and enhanced to increase data mining efficiency and accuracy in order to better forecast the factors behind agronomic traits and disease resistance, therefore speeding up breeding processes.

To improve the agronomic abiotic stress breeding program and find the optimal genotype with essential agronomic features, researchers are currently combining environmental and genotypic data with the observed phenotypic. Given that these are intricate characteristics controlled by factors other than DNA, a sophisticated monitoring system ought to document even the smallest changes or modifications taking place in the plants. To get around this obstacle, researchers have developed a physiological gravimetric system based on artificial intelligence (AI) that can detect even the smallest changes in plants with regard to soil and atmosphere. This system is called the soil-plant-atmosphere continuum (SPAC). With the use of this approach, plant scientists can easily phenotype even the smallest changes in complex features at various stages of plant growth and development. Furthermore, the discovery of stress-responsive Quantitative trait loci (QTLs) or QTLs associated with significant agronomic features can be facilitated by the continuous and rigorous monitoring of these phenotypic data and the subsequent analysis of these data using the Next-Gen AI technique. Additionally, a field phenomics suite has been developed to speed up breeding projects by offering high-resolution photos that make it simple to distinguish between genotypes that perform better in big populations. Using unmanned aerial vehicles (UAV) and ground-based equipment, the field phenomics suite uses a machine learning approach to collect high-throughput phenotypic data pertinent to breeding projects. High-resolution cameras and sensors are installed on this UAV and ground-based apparatus to produce detailed data from thousands of plants cultivated in the field. Breeders can then discover superior genotypes exhibiting the highest agronomic/disease-resistant features by using AI or specialized software to assess the generated data [18].

Many precisions agricultural apps presently use AI, which enables farmers to take prompt action. IoT sensors and UAVs on a normal farm generate millions of data points per day, creating a vast amount of data—also known as big data. This huge data will often be sent to the cloud, where artificial intelligence (AI) will be employed to deduce its meaning. With the aid of artificial intelligence (AI), precision farming uses data from Internet of Things (IoT) sensors placed throughout the field to forecast crop yield, other relevant natural weather conditions, and the occurrence of Catastrophic events [3]. This will ultimately help to meet the present demand for agricultural food production in the long run. Therefore, it is considered crucial to adopt these precision agricultural techniques to the greatest extent feasible. Through the creation of an ML-powered crop recommendation platform, ML contributes to precision farming by enabling farmers to choose which crops to harvest based on established environmental criteria. Generally speaking, ML simulates human problem-solving skills and enables learning without explicit programming. Throughout the whole growing and harvesting cycle, ML can be used as a crucial decision-making tool in precision farming. Generally speaking, this starts with crop prediction, followed by soil preparation and selection, water need prediction, crop yield prediction, and, lastly, agricultural robots gather the produce by using computer vision techniques to assess the freshness and quality of the fruits.

Public sector plant breeding initiatives like those run by the One CGIAR (Consultative Group for International Agricultural Research) program could be completely transformed by AI technologies. AI-enabled breeding systems are using sophisticated processing and analysis algorithms to speed up the breeding process. AI has clearly shown promise in gene identification and allele mining, but its real potential lies in helping biological designers create agricultural cultivars that are suitable for anticipated future circumstances [19].

2.2 AI IN ANIMAL RESEARCH

In animal biotechnology the combination of Machine Learning and Artificial Intelligence is transforming the industry, especially in developing nations where livestock and agriculture are important economic drivers [20].

The integration of AI and ML into animal research has shown promising potential to enhance translation and reproducibility, complementing traditional approaches such as animal models [21]. Researchers can derive more valuable insights from animal trials because to this integration. Findings can be more effectively translated when AI/ML evaluations of animal model data are combined with clinical data from humans. By bridging the gap between preclinical and clinical research, this integrated strategy increases the applicability of results from animal models to human illness. In order to find dysregulated pathways linked to excitatory neurotransmission, a process essential to brain function, transcriptomic analysis the study of gene expression patterns in postmortem human brain tissue from Alzheimer's disease patients and mouse models of the disease was carried out with the aid of machine learning. By optimizing medicine dosage in mice models of epilepsy using machine learning algorithms, dosing schedules that minimized possible toxicities and decreased seizure frequency and severity were found. Researchers can find similarities and differences between species by utilizing AI/ML to integrate massive data from human studies and animal models. For animal behavior pose estimation, a number of systems use deep learning approaches, such as MoSeq, DeepHL, DeepPoseKit, SLEAP, and DeepLabCut. One popular deep learning tool for behavioural analysis is DeepLabCut, which addresses many animal posture restrictions and offers reliable behaviour recording in a variety of settings. More thorough and impartial evaluation techniques are required due to the complexity of animal wellbeing and the complex interactions between behavioral, physiological, and physical aspects. Artificial intelligence (AI) and sensor technology play a crucial role in this situation. These technologies present attractive ways to transform livestock production in the era of digital transformation [22].

Numerous data points, including body temperature, heart rate, activity patterns, dietary habits, and environmental variables, can be continuously recorded by sensor technologies, such as wearable technology and environmental monitoring systems.

These data can offer objective, comprehensive, and real-time insights into animal care when combined with AI systems. More informed, fast, and precise decision-making is made possible by these technologies, which offer continuous, real-time data on a variety of behavioural, environmental, and physiological characteristics. The field of sensor technology application in cattle husbandry is dynamic and developing quickly. In dairy farming, wearable sensors are being utilized more and more to track the health, feeding habits, and estrous cycles of cows. By warning farmers of any health problems or when a cow is ready for insemination, these systems help increase the production and health of the herd. To keep chicken houses at the ideal temperature, humidity, and ventilation, environmental sensors are utilized extensively in poultry production. Complex behavioural data can be analyzed by AI to reveal information on the mental health of animals. For example, pig behaviours using video data have been classified using machine learning algorithms, which have identified behaviours linked to stress or comfort. Farmers can use this knowledge to control social dynamics within a herd and improve living circumstances.

AI-powered monitoring systems are also capable of highly accurate data analysis, identifying health problems or behavioural abnormalities in animals early on. Farmers and veterinarians have less work to do thanks to this technology. The most effective ML apps use deep learning and medical imaging data to diagnose illnesses.AI-based analytics combined with real-time animal monitoring can save lives and enhance animal welfare. By examining past data and finding trends, AI can forecast disease outbreaks and other health problems, assisting authorities and farmers in taking preventative or mitigating action. AI also has potential in the field of treatment optimization [23]. AI-powered data-driven decision support systems assist veterinarians in creating individualized treatment regimens for their patients by considering the animal's genetic makeup, medical history, and drug responsiveness. This optimization facilitates the process of choosing appropriate medications, determining appropriate dosages, and evaluating the efficacy of different therapeutic approaches.

Although there are many potential advantages to using artificial intelligence (AI) in animal welfare and health, there are also a number of drawbacks and difficulties. Collaborating across several areas and organizations to collect comprehensive datasets that contain clinical, neuroimaging, genetic, and biochemical information from both human and animal populations is the most significant obstacle. Prioritizing ethical considerations in the usage of AI/ML technologies is essential as they develop, especially when handling sensitive data. The integrity of research projects and the preservation of public confidence depend on protecting privacy and using appropriate data handling procedures [24].

2.3 AI ENHANCED BIOINFORMATICS

AI is rapidly reshaping Bioinformatics, allowing for a better knowledge of life processes, improving disease diagnostics, and eventually leading to the development of individualized medicinal tactics. The use of artificial intelligence (AI) in computational biology approaches could provide considerable benefits in easing structural biologists' expanding workloads. Classical bioinformatics depended on rule-based algorithms, statistical approaches, and manual biological data interpretation. The transition from conventional to smart bioinformatics represents a huge step forward in the field, owing mostly to advances in AI, machine learning, and big data analytics. AI-based bioinformatics techniques introduce various random fluctuations or mistakes, distorting the quality and dependability of studies [25].

Machine learning algorithms can analyze large datasets, identifying hidden patterns and making more accurate predictions. Challenges include model interpretability and potential biases. Geometrics, a newly created computational tool, encodes protein structures into "shape-mers" utilizing moment invariants, which are mathematical representations of shape that stay consistent when scaled, rotated, or translated. Geometrics facilitates efficient comparison and classification of protein structures [26]. Biomedical data science comprises a variety of data kinds, including gene sequences, omics, imaging, clinical, and structured/unstructured biomedical texts, with machine learning algorithms typically employed for multimodal data analysis and interpretation. [27].

The primary use of artificial intelligence techniques is the determination of genetic characteristics. AI provides the most cost-effective techniques for automating the discovery of previously unknown extrapolative linkages from large data sets in bioinformatics databases. To measure the function of proteins, they are classified into different classes based on the functions they perform [28]. ML in bioinformatics has a wide range of applications, including facilitating gene editing operations, identifying protein structure, detecting disease-associated genes, and repurposing pharmaceuticals [26]. ML is especially useful for predicting large datasets, and human-in-the-loop can improve explanatory power by eliminating hits that are not realistic for the studied ecosystem. The combination of omics data, bioinformatics, and machine learning will facilitate the transition from explanatory data to applications in fields such as medicine, agriculture, and forestry [29].

2.4 AI FOR BETTER HEALTHCARE

AI is used in healthcare to investigate massive volumes of patient data, such as medical records, imaging scans, and laboratory findings, in order to help clinicians make better decisions and improve patients' outcomes. AI systems can make individualized recommendations that aid patients stay healthy. This information can assist patients in better understanding their health and making educated decisions regarding their treatment. AI has proved significant potential in the areas of medical record mining, treatment planning, robotic-assisted surgeries, medical management, and hospital operations support, clinical data interpretation, clinical trial participation, image-based diagnosis, preliminary diagnosis, virtual nursing, and connected healthcare devices [30]. AI in healthcare provides two possible advantages over human performance. First, AI can learn from large amounts of data more effectively than clinicians. Second, AI systems can accomplish predefined tasks with improved precision. AI can be in a constant active state without impairing its performance, therefore it does not suffer from burnout like humans do. These technologies provide numerous advantages that have the potential to greatly improve patient care, healthcare outcomes, and streamline various healthcare operations [32], [31]. Another key use of AI in healthcare is remote monitoring. Patients' vital signs can be watched and monitored remotely using AI-powered systems, alerting healthcare providers to any possible concerns. This can result in early intervention, better patient outcomes, and fewer in-person visits to healthcare facilities. Remote medical care allows individuals to obtain medical treatment without having to travel to a healthcare centre. This is particularly beneficial for people who reside in distant places or have mobility issues.

Medical radiography is critical in the diagnosis and treatment of many medical problems, and the use of AI offers the potential to enhance this important field in a variety of ways. One of the primary applications of artificial intelligence in medical radiography is the analysis of medical images such as X-rays and CT scans. AI algorithms can analyze these photos, detect anomalies, and help with the diagnosis of a variety of medical illnesses. This has the potential to significantly enhance the speed and accuracy of diagnostics, resulting in better patient outcomes [32]. As a result, training AI-based tools on doctors' subjective reactions that carry over individual biases would be difficult without knowledge of the ground truth. Furthermore, AI research must account for the differences in medical problem features between healthcare applications. A tailored AI approach may be required for each application depending on the type and amount of data available, the target patients, the degree of variability and meaningful information in the data, and the nature of the healthcare choices to be made [30].

Ntuitive Surgical's Da Vinci robotic surgical technology has transformed the area of surgery, particularly urology and gynaecological surgeries. The system's robotic arms replicate a surgeon's hand movements with more precision and include a 3D view and magnification settings that allow the surgeon to execute minute incisions. AI was used to evaluate existing drugs that could be utilized to combat the developing Ebola virus threat, which would have taken years to process otherwise. With AI's assistance, we would be able to readily accept the new concept of "precision medicine." [31].

AI is transforming the field of customized medicine, providing novel prospects for medical treatment and care to individual patients [25]. AI systems offer medical professionals real-time clinical decision support, including evidence-based recommendations for treatment regimens, drug interactions, and diagnostic accuracy. This helps clinicians to make more informed decisions [9]. Physical examinations, clinical laboratory reports, operation notes, and discharge summaries are examples of unstructured and incomprehensible data for a computer program [33]. With the development of ML-based methods, it has become relatively easier to determine the three-dimensional structure of a target protein, which is a vital step in drug discovery, because novel medications are generated based on the three-dimensional ligand binding environment of a protein. Recently, Google's Deep mind launched AlphaFold, an AI-based tool trained on PDB structural data that can predict the 3D structure of proteins based on amino acid sequences [25].

3. HURDLES AND FIXES IN AI TECHNOLOGY

3.1 UNVEILING AI APPROACHES

Explainability enables academics, policymakers, and other stakeholders to comprehend how the AI system makes decisions and whether those judgments are consistent with their beliefs and objectives in the biotechnology sector [29].AI systems are frequently employed in the biotechnology industry to evaluate vast volumes of data and provide forecasts or suggestions that may have a big impact on environmental safety, public health, and other crucial areas. People may find it challenging to trust the accuracy and dependability of an AI system's outputs if it cannot clearly explain how it arrived at a specific conclusion or forecast. Because it enables people to comprehend and assess the AI system's decision-making processes and to make sure that it is being utilized responsibly and advantageously, explainability is a crucial component in guaranteeing the reliability and moral use of AI in the biotechnology sector. AI is frequently praised for its sophisticated abilities, which allow it to replace human intellect in tasks requiring sophisticated reasoning, problem-solving, and complicated thinking.

AI has left its mark on education through a range of technologies, including conversational agents, adaptive learning environments, intelligent tutoring systems, automated assessment tools, and advanced data analysis tools. The investigation of AI's lesser-known facets will cover topics like the disruption of conventional pedagogical relationships, potential biases encoded in educational algorithms, privacy issues related to student data management, and the escalation of digital divides. It seeks to shed light on AI's shadow side, which contains unintended and frequently disregarded effects on cognitive development, social interactions, and learning autonomy. These are important issues that educational stakeholders need to address in order to responsibly and ethically harness AI's potential [34].

3.2 HUMAN AI SYNERGY

The UN Committee on World Food Security's High-Level Panel of Experts on Food Security and Nutrition (HLPE) prepared the 15th Food Security and Nutrition: Building a Global Narrative Towards 2030 report, which emphasized the need to move beyond the conventional four-pillar framework for food security—namely, availability, access, utilization, and stability—to a six-dimensional one that incorporates agency and sustainability. A policy that promotes all facets of food security ought to be created in order to boost the resilience of food systems. This is particularly crucial in situations like the present food crisis brought on by the conflict in Ukraine. The COVID-19 epidemic underlined the need for reform of food systems worldwide. It is necessary to look for innovative ways to increase agricultural output and decrease food waste. During emergencies like a pandemic or war, information technology (IT) solutions are particularly crucial because they can be used to automate industries using smart sensors, which reduces contact and communication with items and allows for remote monitoring [35]. Medical devices that use artificial intelligence and machine learning (AI/ML) seek to enhance patient care by gleaning fresh ideas from large amounts of data produced by both individual patients and the combined experiences of several patients. According to the Food, Drug, and Cosmetic Act (in the USA), Council Directive 93/42/EEC (EU nations), and Therapeutic Products Act (in Switzerland), AI/ML-based software is considered a medical device when it is meant to diagnose, treat, or prevent health issues.

The FDA gives examples of AI/ML-based devices in the real world, including a smart ECG gadget that calculates the likelihood of a heart attack or an imaging system that employs algorithms to provide diagnostic information for skin cancer [36]. During a pandemic, social media can also be a useful tool for informing the public about health issues. The public nearly always uses and consumes more media in all forms as a result of emerging infectious diseases like COVID-19 in order to obtain knowledge. Consequently, people's perceptions of disease exposure, the decisions that follow, and their risky behaviours are greatly influenced by social media [37]. Setting standards for the clinical validity of AI technologies is a regulatory challenge. From the standpoint of the patient, a regulatory framework sets down not just safety guidelines but also restrictions regarding consent, particularly in cases where patients actively participate in the development of AI[38].

AI has been applied in recent years to enhance healthcare delivery in a number of ways, including by facilitating remote monitoring, virtual consultations, and the provision of tailored health in format: The accuracy of diagnosis and patient outcomes could be significantly enhanced by the application of artificial intelligence (AI) in medical radiography. The diagnosis and treatment of many medical disorders depend heavily on medical imaging, and artificial intelligence (AI) has the potential to improve this vital sector in a variety of ways. Lastly, by giving patients more information about their health and the treatments they are receiving, AI can improve healthcare transparency. In addition to fostering trust between patients and healthcare professionals, this can enable patients to make knowledgeable decisions regarding their care. The manner that medical and dentistry students are taught is probably going to undergo much more exciting changes as AI develops. AI has the potential to assist raise the standard and effectiveness of healthcare education and give aspiring medical professionals the information and abilities they need to give their patients the best care possible, provided that the appropriate research and regulations are in place [32].

3.3 ETHICAL CONSIDERATION IN AI

Pharmaceuticals are strictly regulated in medicine and must be supported by clinical trial findings before they can be licensed. When it comes to AI, investigations should be performed on a system comprised of AI and the humans who use it, as the outcome is decided by AI and how it is used [10]. As AI and robotics become more incorporated into life science systems, vital ethical considerations emerge. These consequences concern privacy, data security, accountability, openness, fairness, and human autonomy [9]. In practice, a variety of deeper systemic concerns arise, which include and extend beyond the accuracy of Computer Aided Detection (CAD), and are related to the ethical aspect of the systems. Figure 1 depicts a schematic illustration of the five bioethical principles considered [39].

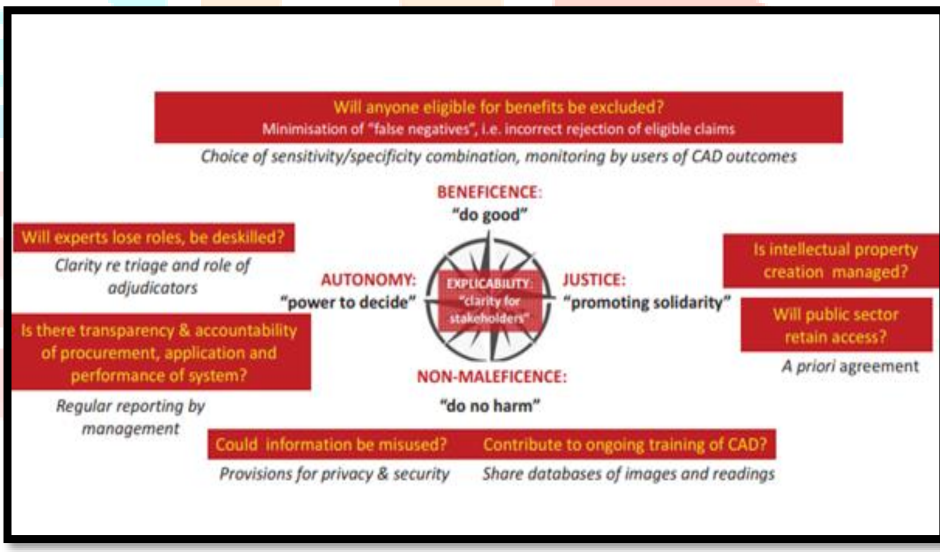

Figure 1: Principles of Bioethics in relation to CAD

As we move forward, we must acknowledge that the ethical path of AI and robotics is continuous. Continuous reflection, adaptation, and collaboration will be required to fully realize the potential of these technologies while preserving human well-being and trust [9]. Clinicians and patients have access to the world's top LLM expertise. They may be able to synthesize human knowledge, and LLMs with specialized training can offer expert advice comparable to that of the greatest medical practitioners. This reduces patient risk while improving medical diagnosis and treatment outcomes. In this view, it meets the two-core biological ethical criteria: beneficence and nonmaleficence [10].

CONCLUSION

AI is a significant force behind Biotechnology firms' current and future innovation. Its increasing use demonstrates how well technology can streamline procedures, workflows, and methods, providing businesses with a competitive edge. The main Instruments for putting value-creating concepts into practice and bringing them together are the quickly developing technology. As a result, using AI and associated technologies is a trend that businesses must embrace and use to gain a competitive edge rather than a choice. As covered in the review above, operations including pharmaceutical manufacturing, animal development, agricultural field monitoring, personal nutrition tracking, and similar biological activities require robust AI software solutions to expedite development and lower human error. Nevertheless, despite its capacity for transformation, issues including data privacy, ethical ramifications, the correctness of biological data sets, decision-making biases, and its reliability have also been examined. Furthermore, taking into consideration its uses and difficulties during development will allow people to carry out jobs in which they are capable while adhering to moral and ethical standards.

In the coming years, artificial intelligence (AI) will play a crucial role in Biotechnology, facilitating creative breakthroughs in biological sciences and technology for the benefit of humanity.

ACKNOWLEDGMENT

The authors show their gratitude to the authorities of CMS college of Science and Commerce, Coimbatore, Tamil Nadu, India for the facilities.

REFERENCES

1. Andresen, S. L. (2002). John McCarthy: father of AI. *IEEE Intelligent Systems,* 17(5), 84-85.
2. Tagde, P., Tagde, S., Bhattacharya, T., Tagde, P., Chopra, H., Akter, R., & Rahman, M. H. (2021). Blockchain and artificial intelligence technology in e-Health. *Environmental Science and Pollution Research*, 28, 52810-52831.
3. Thilakarathne, N. N., Bakar, M. S. A., Abas, P. E., & Yassin, H. (2022). A cloud enabled crop recommendation platform for machine learning-driven precision farming. *Sensors*, *22*(16), 6299.
4. Hassani, H., & Silva, E. S. (2023). The role of ChatGPT in data science: how ai-assisted conversational interfaces are revolutionizing the field. *Big data and cognitive computing, 7(2), 62.*
5. Liyanage., Harshana., Siaw-Teng Liaw., Jitendra Jonnagaddala., Richard Schreiber., Craig Kuziemsky., Amanda L. Terry., and Simon de Lusignan. (2019). Artificial intelligence in primary health care: perceptions, issues, and challenges. *Yearbook of medical informatics* 28, no. 01: 041-046.

6. Cerchia, C., & Lavecchia, A. (2023). New avenues in artificial-intelligence-assisted drug discovery. *Drug Discovery Today*, *28*(4), 103516.

7. Gupta, R., Srivastava, D., Sahu, M., Tiwari, S., Ambasta, R. K., & Kumar, P. (2021). Artificial intelligence to deep learning: machine intelligence approach for drug discovery. *Molecular diversity*, *25*, 1315-1360.

8. Sinz, F. H., Pitkow, X., Reimer, J., Bethge, M., & Tolias, A. S. (2019). Engineering a less artificial intelligence. *Neuron*, *103*(6), 967-979 .

9. Elendu, C., Amaechi, D. C., Elendu, T. C., Jingwa, K. A., Okoye, O. K., Okah, M. J., & Alimi, H.A. (2023). Ethical implications of AI and robotics in healthcare: A review. *Medicine*, *102*(50), e36671.

10. Savulescu, J., Giubilini, A., Vandersluis, R., Mishra, A. (2024). Ethics of artificial intelligence in medicine. Singapore *Medical journal*; 65:150-8.

11. Khan, M. H. U., Wang, S., Wang, J., Ahmar, S., Saeed, S., Khan, S. U., ... & Feng, X. (2022). Applications of artificial intelligence in climate-resilient smart-crop breeding. *International Journal of Molecular Sciences*, *23*(19), 11156

12. Bhagat, P. R., Naz, F., & Magda, R. (2022). Artificial intelligence solutions enabling sustainable agriculture: A bibliometric analysis. *PloS one*, *17*(6), e0268989.

13. Tyczewska, A., Twardowski, T., & Woźniak-Gientka, E. (2023). Agricultural biotechnology for sustainable food security. *Trends in biotechnology*, *41*(3), 331-341.

14. Yang, Y., & Siau K., (2018). A qualitative research on marketing and sales in the artificial intelligence age. *Association for Information Systems Conference,Saint Louis, MO, USA, 17-18* .

15. Konar, A. (2018). *Artificial intelligence and soft computing: behavioral and cognitive modeling of the human brain*. CRC press.

16. Faulkner, A., Cebul, K., & McHenry, G. (2014). Agriculture gets smart: the rise of data and robotics. *Cleantech Agriculture Report. 5-6*

17. Ali, T., Rehman, S. U., Ali S., Mahmood, K., Obregon, S. A., Iglesias, R. C., & Ashraf, I. (2024). Smart agriculture: utilizing machine learning and deep learning for drought stress identification in crops. *Scientific Reports*, *14*(1), 1-16.

18. Rai, K. K. (2022). Integrating speed breeding with artificial intelligence for developing climate-smart crops. *Molecular biology reports*, *49*(12), 11385-11402.

19. Farooq, M. A., Gao, S., Hassan, M. A., Huang, Z., Rasheed, A., Hearne, S., & Li, H. (2024). Artificial intelligence in plant breeding. *Trends in Genetics.* 903-904.

20. Damodhar, P., Siva Kiran, R.R. (2025). The Role of Artificial Intelligence and Machine Learning in Advancing Animal Biotechnology: A Review. *Archives of Razi Institute*.

21. Ghosh, A., Choudhary, G., & Medhi, B. (2024). The pivotal role of artificial intelligence in enhancing experimental animal model research: A machine learning perspective. *Indian Journal of Pharmacology*, *56*(1), 1-3

22. Neethirajan, S. (2024). Artificial intelligence and sensor innovations: enhancing livestock welfare with a human-centric approach. *Human-Centric Intelligent Systems*, *4*(1), 77-92.

23. Ali, A. A., & Al-Zu'bi, M. (2023). Application of artificial intelligence in monitoring of animal health and welfare. *Indian Journal of Animal Research*, *57*(11), 1550-1555.

24. Mittelstadt, B. D., Allo, P., Taddeo, M., Wachter, S., & Floridi, L. (2016). The ethics of algorithms: Mapping the debate. *Big Data & Society*, *3*(2), 2053951716679679.

25. Jamialahmadi, H., Khalili-Tanha, G., Nazari, E., & Rezaei-Tavirani, M. (2024). Artificial intelligence and bioinformatics: a journey from traditional techniques to smart approaches. *Gastroenterology and Hepatology from Bed to Bench*, *17*(3), 241

26. Hashemi, A. S., & Vaisman, I. I. (2025). Topology-based protein classification: A deep learning approach. *Biochemical and Biophysical Research Communications*, *746*, 151240.

27. Karim, M. R., Islam, T., Shajalal, M., Beyan, O., Lange, C., Cochez, M., & Decker, S. (2023). Explainable AI for bioinformatics: Methods, tools and applications. *Briefings in bioinformatics*, *24*(5), bbad236.

28. Rana, V. (2019). Role of Artificial Intelligence in Bioinformatics, *Ind. J. Pure App. Biosci.* 7(6), 317-321

29. Holzinger, A., Keiblinger, K., Holub, P., Zatloukal, K., & Müller, H. (2023). AI for life: Trends in artificial intelligence for biotechnology. *New Biotechnology*, *74*, 16-24.

30. Asan, O., Bayrak, A. E., & Choudhury, A. (2020). Artificial intelligence and human trust in healthcare: focus on clinicians. *Journal of medical Internet research*, *22*(6), e15154.

31. Malik, P., Pathania, M., & Rathaur, V. K. (2019). Overview of artificial intelligence in medicine.*Journal of family medicine and primary care*, *8*(7), 2328-2331.

32. Dave, M., & Patel, N. (2023). Artificial intelligence in healthcare and education. *British dental journal*, *234*(10), 761-764.

33. Jiang, F., Jiang, Y., Zhi, H., Dong, Y., Li, H., Ma, S., & Wang, Y. (2017). Artificial intelligence in healthcare: past, present and future. *Stroke and vascular neurology*, *2*(4).

34. Al-Zahrani, A. M. (2024). Unveiling the shadows: Beyond the hype of AI in education. *Heliyon*, 10(9).

35. Tyczewska, A., Twardowski, T., & Woźniak-Gientka, E. (2023). Agricultural biotechnology for sustainable food security. *Trends in biotechnology, 41(3), 331-341.*

36. Muehlematter, U. J., Daniore, P., & Vokinger, K. N. (2021). Approval of artificial intelligence and machine learning-based medical devices in the USA and Europe (2015–20): a comparative analysis. *The Lancet Digital Health*, *3*(3), e195-e203.

37. Tsao, S. F., Chen, H., Tisseverasinghe, T., Yang, Y., Li, L., & Butt, Z. A. (2021). What social media told us in the time of COVID-19: a scoping review. *The Lancet Digital Health*, *3*(3), e175-e194.

38. Zhou, K., & Gattinger, G. (2024). The Evolving Regulatory Paradigm of AI in MedTech: A Review of Perspectives and Where We Are Today. *Therapeutic Innovation & Regulatory Science*, *58*(3), 456-464.

39. Spiegel, J. M., Ehrlich, R., Yassi, A., Riera, F., Wilkinson, J., Lockhart, K., & Kistnasamy, B. (2021). Using artificial intelligence for high-volume identification of silicosis and tuberculosis: A bio- ethics approach. *Annals of Global Health, 87(1)*.