



## The Future Of Pharmacy: How AI Is Revolutionizing The Industry

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### ❖ Abstract

The application of Artificial Intelligence (AI) is rapidly transforming various industries, and the pharmaceutical industry is no exception. AI is increasingly being used to automate, optimize and personalize various aspects of the pharmacy industry, from drug discovery to drug dispensing. In this context, this paper explores the potential of AI to revolutionize the pharmacy industry, by discussing the current and future applications of AI in the industry. We will examine how AI is being used in drug discovery, personalized medicine, drug safety and quality control, inventory management, and patient counselling. We will also discuss the challenges and limitations of AI in the pharmacy industry, such as data privacy, ethical concerns and regulatory barriers. The paper will argue that AI has the potential to revolutionize the pharmacy industry by enabling faster drug discovery, improving patient outcomes, reducing costs, and increasing the efficiency and accuracy of various pharmacy operations. The old pharmacy system relied on manual processes and human decision-making, while the new AI pharmacy system automates routine tasks, provides personalized treatment plans, and reduces costs while improving patient outcomes. However, it is important to ensure that AI is used ethically and responsibly, and that its impact on the workforce and society is carefully considered. The major benefit of integrating AI into specific applications within the pharmacy field is improved accuracy and efficiency in patient care. Overall, this paper will provide an insight into the future of the pharmacy industry, and the transformative potential of AI in this field.

**KEYWORDS:** Artificial Intelligence, AI, Machine learning, Deep learning, Neural networks, Pharmaceutical Sciences, Pharma Industry, Startups, Drug discovery.

## ❖ Introduction

To meet the needs of society and clinicians in the 21st century, the current drug discovery process needs to shift drastically. In particular, artificial intelligence and machine learning offer the pharmaceutical industry a real opportunity to do R & D differently, so that it can operate more efficiently and significantly improve the early stages of drug development success<sup>[1]</sup> Artificial Intelligence (AI) is the simulation of the human behavior with regard to intelligence processes involved in problem-solving. Such mechanisms include human cognitive science reading, observation, preparation, interpretation, reasoning, correction, speech recognition, linguistics, and other sources<sup>[2]</sup>. For this, AI uses Natural Language Processing (NLP) in order to understand natural human communication and translates it internally to a code that machines comprehend. AI also depends on Deep Learning (DL) to accomplish this task. Through the application of these technologies, AI trains computers to perform specific tasks with the least amount of human intervention by processing large data volumes and recognition of familiar or new patterns in data<sup>[3]</sup>. At Dartmouth college conference the term “Artificial Intelligence” was coined in 1956 by a scientist, John McCarthy who is considered as father of artificial intelligence. The term Artificial Intelligence has gained its importance today because of larger data volumes, advanced algorithms and programming, and advancements in computer storage and power.<sup>[4]</sup> Recently and largely because of the developments in deep learning that demonstrated incredible precision in image recognition and autonomous driving<sup>[5]</sup>. The use of artificial intelligence, and in particular the deep-learning subtype, has been allowed across all sectors through the use of marked big data, together with significantly enhanced computing power and cloud storage.<sup>[6]</sup>

## ❖ Objectives of AI

- Creation of Expert Systems: It involves the creation of automated systems that exhibit intelligent behavior and advice humans on the right course of action.
- Implementation of Human Intelligence in Computers <sup>[7]</sup>: It will help create identical cognitive patterns in computers which will help them behave like humans and take appropriate actions to solve complex problems. This will enable automated processes and reduced human workload through the application of algorithms.
- Multi-Domain Application: AI will help in multiple domains of implementation like Computer Science, Cognitive Science, Statistics, Psychology, Medical Science, Engineering, Ethics, Natural Sciences, Healthcare, Space Technology, Logic, Linguistics, E-commerce, and more.
- Applications in Computer Science: AI helps in developing a number of mechanisms to solve many difficult problems in the field of computer science like Search and Optimization, Logic, Control Theory, Language Analysis, Neural Networks, Classifiers, and Statistical Learning Methods, and Probabilistic Methods for uncertain reasoning.

## ❖ Need for AI in pharmacy machine

Even as there may be a developing hobby in the use of AI in pharmacy structures, it's miles critical to notice that its implementation ought to be carefully considered and deliberate. whilst AI has the capability to revolutionize the enterprise by offering personalized medicinal drug management and 24/7 guide to patients, it is critical to ensure that it's far used ethically and that capacity barriers and demanding situations are addressed. consequently, a thoughtful and evidence-based totally technique is wanted to make sure that AI is used successfully and responsibly in the pharmacy device. The developing populace will benefit from the implementation of AI in the drugstore machine as it could help deal with the increasing demand for healthcare services. With personalised medicinal drug control and 24/7 support, AI can help sufferers manipulate their medicinal drugs more effectively, decreasing the need for frequent visits to healthcare providers. This can help ease the weight on the healthcare device and enhance get admission to care for patients. moreover, AI can doubtlessly lessen medication errors and damaging drug interactions, improving affected person outcomes and decreasing healthcare prices. by using enhancing medicine management and decreasing the workload on healthcare companies, AI can help cope with the demanding situations associated with the developing populace and the growing demand for healthcare offerings. The implementation of AI inside the pharmacy gadget can help make the global a higher location in numerous approaches. first of all, it could improve get admission to healthcare services by way of imparting personalized medication control and 24/7 assist to patients [8,9,10]. This could assist sufferers control their medications greater correctly and reduce the want for common visits to healthcare companies, which can be in particular beneficial in areas where healthcare offerings are limited or inaccessible. Secondly, AI can potentially reduce healthcare expenses by minimizing medication mistakes and preventing damaging drug interactions, resulting in fewer hospitalizations and decrease healthcare charges. Thirdly, AI can lessen the workload on healthcare companies, permitting them to cognizance on more complicated obligations and improving the fine of care they are able to offer. usual, the implementation of AI in the pharmacy gadget has the capacity to enhance healthcare outcomes, lessen healthcare charges, and increase get admission to healthcare offerings, making the world a better vicinity for everyone [11,12,13].

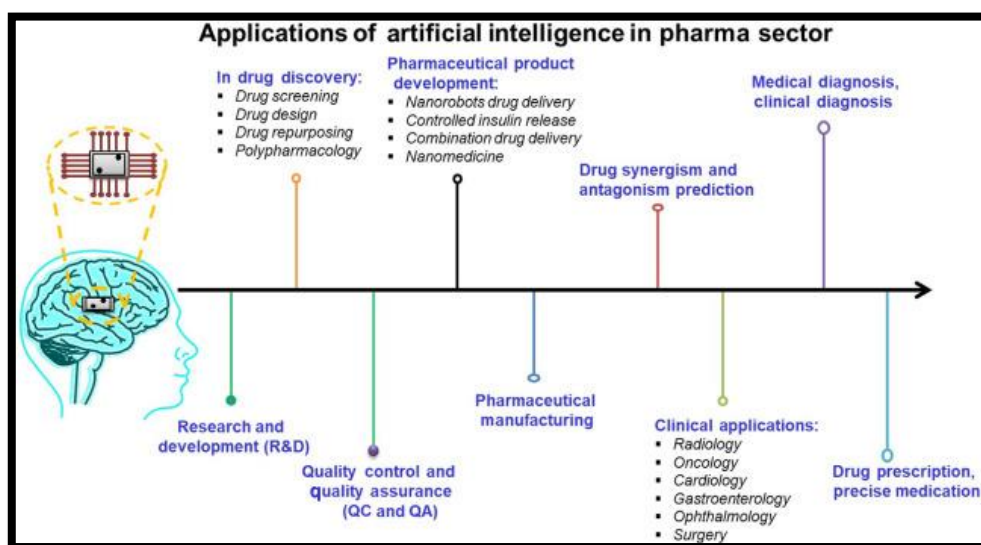


Figure 1: Application of AI

## ❖ Types of Artificial Intelligence

As per Arend Hintze, the AI technology based upon their existence as follows:<sup>[14]</sup>

Type 1: Weak AI or Narrow AI which is focused on one narrow task, not too intelligent to do their own work. Eg. poker game in which all rules and moves are fed into the machine.

(b) Strong AI: The machines that can actually can think.

Type 2: Based on functionalities it is classified as;

(a) “Reactive Machine” which is one of the basic forms of AI which doesn’t have past memory and cannot use past information to information for the future actions. Eg. IBM chess program that beat Garry Kasparov in the 1990s.

(b) “Limited Memory” in which the AI systems can use past experiences to inform future decisions. Some of the decision-making functions in self driving cars have been designed this way. Observations used to inform actions happening in the not so distant future, such as a car that has changed lanes. These observations are not stored permanently and also Apple’s Chatbot Siri.

(c) Theory of Mind: This type of AI should be able to understand people’s emotion, belief, thoughts, and expectations and be able to interact socially.

(d) Self-awareness: An AI that has its own conscious, super intelligent, self-awareness and sentient or in simple words act as a complete human being.

## ❖ Technologies used in AI

- **Natural language processing (NLP):** program computers to process and analyze large amounts of natural language data.
- **Support vector machine (SVM):** Given a labeled training data (supervised learning), the algorithm outputs an optimal hyperplane which categorizes new examples.
- **Heuristics:** mental shortcuts that ease the cognitive load of making a decision. Eg., using a rule of thumb, an educated guess, an intuitive judgment, a guesstimate, profiling, or common sense.
- **Artificial neural networks (ANN):** Started in way back in 1940s, is an information processing model that is inspired by the way biological nervous systems, such as the brain, process information. An artificial neuron is a mathematical function. ANN takes data samples rather than entire data sets to arrive at solutions, which saves both time and money. ANNs have three layers that are interconnected (PYTHON). Neural networks learn things in exactly the same way as the brain, typically by a feedback process called back-propagation (backprop). ANNs are used in Self Driving cars, Character Recognition, Image Compression and Stock Market Prediction. Based on their pattern of association ANNs are classified as supervised 'associating networks, Unsupervised feature-extracting networks and Non-adaptive unsupervised networks. The potential applications of ANN methodology in the pharmaceutical sciences range from

interpretation of analytical data, image recognition, drug and dosage form design through biopharmacy to clinical pharmacy<sup>[15,16]</sup>.

### ❖ AI Market in Health Care

According to venture capital firm Rock Health, 121 health AI and machine learning companies raised \$2.7 billion in 206 deals between 2011 and 2017. The value of 10 promising AI applications and found that they could create up to \$150 billion in annual savings for U.S. health care by 2026. Reducing health costs by Image processing, safeguarding patients' personal records against cybercriminals and assisting in surgeries. AI-enabled workflow assistants are aiding doctors free up their schedules, reducing time and cost. AI helps pathologists in analyzing tissue samples and thus, in turn, making more accurate diagnosis. As per Harvard Business Review and Accenture, there are 10 potential applications of AI which could change the health care industry.

Health Application	Motivation for adoption
Robot assisted surgical operation	Technological advances in robot answer for more types of surgical operation
Virtual nursing assistants	Growing strain as a result of medical hard work scarcity
Administrative workflow	Simpler integration with present era infrastructure
Fraud detection	Want to deal with an increasing number of complicated provider and price fraud attempts
Dosage error reduction	Prevalence of scientific mistakes, which leads to tangible penalties
Connected machines	Proliferation of connected machines/gadgets
Clinical trial participation	Patent cliff; plethora of data; results-pushed approach
Preliminary diagnosis	Interoperability/facts architecture to beautify accuracy
Autonomous image diagnosis	Storage potential, greater consider in AI technology
Cyber security	Boom in breaches; stress to defend health records

Table 1: Ten potential health applications and potential motivation for adoption



## ❖ AI in Pharma Industry

An enormous amount of estimated US\$ 2.6 billion over more than 10 years is spent on developing a drug. In spite of this spending nine out of ten candidate therapies fail between phase I trials and regulatory approval<sup>[17]</sup>. As described in the report by Codrin Arsene, CEO of Digital Authority Partners, Artificial intelligence in Pharma refers to the use of automated algorithms to perform tasks which traditionally rely on human intelligence. Over the last five years, the use of artificial intelligence in the pharma and biotech industry has redefined how scientists develop new drugs, tackle disease, and more<sup>[18]</sup>. Machine learning and other technologies are expected to make the hunt for new pharmaceuticals quicker, cheaper and more effective. A report by the HIMSS Analytics 2017 Essentials Brief shows that less than 5% of healthcare organizations are currently using or investing in AI technologies<sup>[19]</sup>. Leading pharma companies are progressing towards using AI for certain strategic applications. AI will help the pharma companies to increase the success rates of new drug discovery meanwhile decreasing operational costs<sup>[20]</sup>. McKinsey predicts that better decision-making, optimized innovation, enhanced testing performance, clinical trials, and new tool development could produce up to \$100b in pharmaceutical and medicine annually with the aid of big data, AI and machine learning<sup>[21]</sup>.

Company	Strategy of using AI
Expectation 1. Development of new drugs and biomarkers <sup>[22]</sup>	
Novartis	Novartis is the usage of device learning to classify digital pics of cells that are handled with new compounds (tablets) for grouping the compounds having comparable effects. to hurry up the screening system pictures from gadget mastering algorithms to expect which untested compounds is probably beneficial and do really worth exploring extra details.
Berg	evolved an AI version to identify previously unknown most cancers mechanisms in more than 1000 cancer and healthy cellular samples.
Wuxi NextCODE	Develops drugs and check them in scientific trials by way of sophisticated pattern popularity.
Verge Genomics	it is developing new capsules by using automating facts amassing and analysis to create solutions to a number of the most complex sicknesses acknowledged today, including ALS and Alzheimer's are expecting the effect of recent remedies the use of AI.
Expectation 2. Tackling of diseases which were difficult to treat earlier	
Tencent Holdings and Medopad	AI facilitated telephone apps will screen how a affected person opens and closes their arms and captures the movements to decide the severity of their Parkinson's disorder signs and symptoms.
Mission Therapeutics	the usage of AI to expand Deubiquitinase (DUB) inhibitors in the combat in opposition to Alzheimer's and Parkinson's.

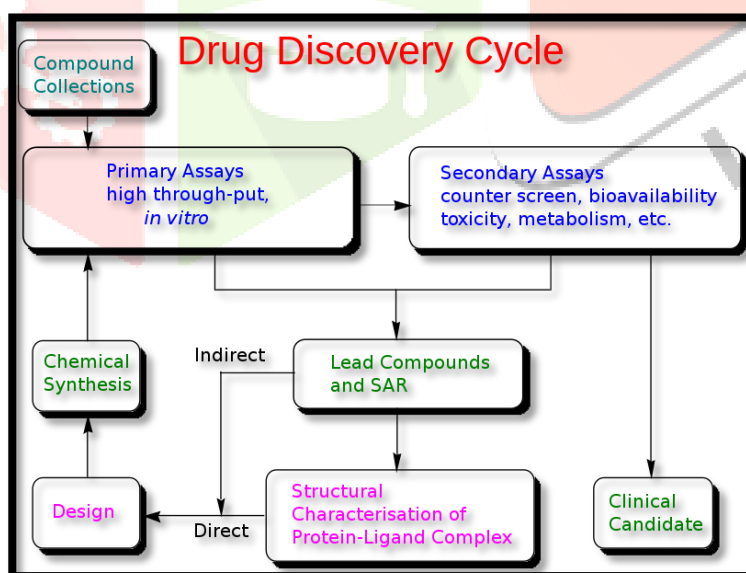
Healx	uses AI based platform HealNet that allows scientists to increase manufacturing in disease drug discovery while simultaneously reducing time, fee and threat.
Expectation 3. Drug adherence among volunteers during clinical trials	
AiCure and AbbVie	uses AI primarily based mobile SaaS platform for image recognition to enhance drug adherence.
CURATE	An AI based totally platform constructed by means of national college of Singapore, to forestall the advanced cancer disorder progression by optimizing drug dosage at an character affected person stage.
Expectation 4. Better analysis and utilization of clinical data	
IBM Watson	Uses a deep herbal language processing and reasoning algorithm which helps clinicians to identify patient's health attributes against clinical trial requirement, thereby allows clinicians to find potentially eligible sufferers for scientific trials.
BenevolentBio	AI platform, into which the information from sources consisting of research papers, patents, scientific trials and affected person facts are fed to produce information graphs
Apple's ResearchKit	An open supply framework that lets in researchers to create apps dedicated to medical care. It makes use of AI to screen youngsters for autism through amassing facts from its iPhone and Apple watch products to improve fitness care.
5. Finding the correct patients for clinical trials and reducing turnaround times	
Antidote	It makes use of NLP reads unstructured data entered to display screen sufferers for drug trial enrollment by means of simplifying the complexity of the inclusion/exclusion criteria in clinical trials. earlier, this turned into traditionally near not possible for a normal computer to understand the unstructured records.
Santen and twoXAR	Developed AI based drug discovery platform to find out, display screen, and prioritize novel drug candidates for ocular troubles.

Table 2: Expectations and strategies of using AI in pharma industry

## ❖ AI in Drug Discovery

There are five stages of drug development process where AI and ML could be employed. Machine learning and artificial intelligence are transforming the process of scientific discovery by allowing scientists to see deeply into vast research data sets and augment scientific intuition.<sup>[23]</sup> BenevolentAI used this technology to identify several compounds, including compound A, which may have therapeutic potential in (Amyotrophic Lateral Sclerosis) ALS<sup>[24]</sup>. BenchSci and The Science Academy conducted survey in December 2017 and found that the stages where AI is used in drug discovery process include: Target identification and validation, Safety tests, Compound discovery, Lead optimization, Preclinical studies, Formulation, Clinical studies including clinical trial recruitment, Approval, Marketing and Post-marketing surveillance<sup>[25]</sup>. There are many AI drug discovery startups offering solutions for every phase of the process, from research to publishing. As on November 13, 2019 there are about 167 startup companies using AI for drug discovery and an exhaustive list of these startups are published with hyperlinks for convenience of the reader<sup>[26]</sup>. Based on the importance and gaining popularity of AI in drug discovery, Journal of Medicinal Chemistry of ACS publications is planning to publish a special issue on “Artificial Intelligence in Drug Discovery”<sup>[27]</sup>. The leading 10 disease types considered in the artificial intelligence (AI) literature through searching the disease types in the AI literature on PubMed are Neoplasm, Nervous, Cardiovascular, Urogenital, Pregnancy, Digestive, Respiratory, Skin, Endocrine and Nutritional.

Figure 2 : Drug Discovery Cycle



## ❖ Automation of Community and Hospital Pharmacies

Robots may already be better at doing this than humans, according to KQED Science. Actually, "it's a perfect job for a robot: a boring and repetitive mission," the author wrote. However, many doctors are optimistic about the potential for automation that allows pharmacists to reinvent themselves as a profession rather than being afraid. Unless pharmacists are hoping to survive AI's growth, they need to find a way to use it for their benefit without allowing robots to completely replace them—a truly delicate balance. The fact that the robots did not



actually take jobs away from pharmacy technicians is important to note here, instead they created an opportunity for the technicians to concentrate on other more important work.

### ❖ **AI in Pharmaceutical Marketing**

Successful pharma brands in 2023 will employ AI in all aspects of their marketing. Every minute of every day, people, machines, sensors and devices generate unimaginable amounts of data. Cloud computing, smart phones and social media platforms are everywhere. Everyone is connected—three billion people online, five billion mobile phones, and six billion devices connected. McKinsey Podcast says that the Real-World Potential and Limitations of Artificial Intelligence – healthcare is likely to be one of the industries where AI has the greatest financial impact, at nearly \$400 billion.<sup>33</sup> It is projected that the data we produce will increase tenfold between 2016 and 2015 to 163 zetta bytes. In the future, data volume will be measured in yottabytes—a number with 24 zeros<sup>[28]</sup>. The General Data Protection Regulation (GDPR) is Europe's new framework for data protection laws, effective as of May 2018. Any company that stores or processes personal information about EU citizens must comply with the GDPR. Companies that fail to comply could face steep fines. The way AI manages customer service requests in Pharma Marketing: forecasts, study 2018-2023 reveals that Chatbots handles customer service requests. Hyper-smart marketing technology is leading to greater ROI. Predictive models help us understand the consequences of compliance and drop-off. There are already a lot of AI-powered applications like these. Over the next five years, they will strengthen in number and power, and will be joined by others standing on their shoulders to go even further, especially in decisions on coverage, reimbursement, and treatment. A recent survey by the World Federation of Advertisers found that the greatest skills gap between current and future needs is AI predictive modeling. Simply put, the modern pharma marketers who succeed will be the ones who understand what successful people have always grasped: what tools to work with, how to use them, and how to work with the right people<sup>[29]</sup>. In reality, only 15% of companies used AI this time last year and 31% expected to use it within a year. The technology could turn pharmaceutical sales in 2019, according to Veeva<sup>[30]</sup>. Just as the digital revolution of the 1990s required individuals across the company to build their knowledge and work together, the AI revolution will do the same. Teams across organizations will be tasked with working together to find new and better ways to identify, collect, share, analyze, interpret, and act on data. The impact of AI on pharmaceutical sales can start before the sales rep meets a customer. Machine learning can separate customers into highly specific segments, allowing sales teams to personalize their activity to greater degree. According to Accenture, AI could help workers to use their time more efficiently, increasing labour productivity by up to 40%—just the sort of boost that sales reps need. Pfizer Australia teamed up with AI provider, Complexica, back in 2017 to simulate sales and marketing strategies and resolve tricky 'what-if' scenarios.

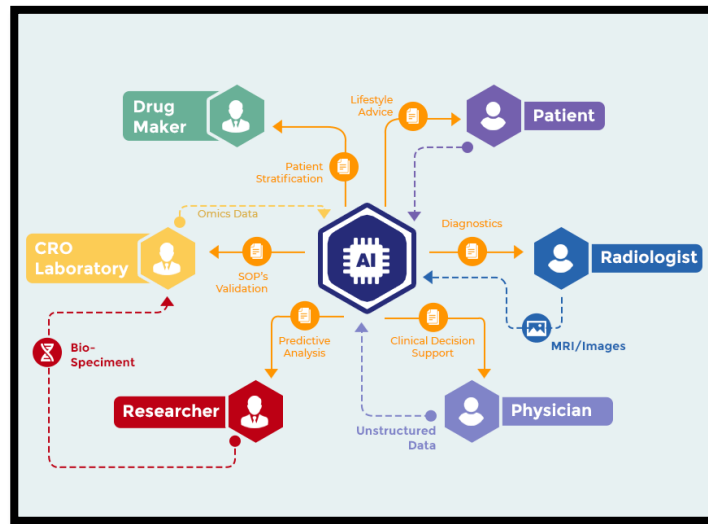


Figure 3 : AI in Pharmaceutical Marketing

### ❖ Future of Artificial Intelligence

Companies like Google and Uber are already using AI capabilities to power self-driven cars. AI will have a great bearing on the automated transportation field by aiding handicapped drivers and preventing accidents. More evolved AI systems will support in hazardous factory-based jobs and may replace humans as well. Climatic change predictions can be made by AI systems using data sciences and environmental technologies. Around 80 percent of customer service operations will be handled by effective and timely AI systems. Personalized health management will be made easier through AI systems symptom-identification and medical data processing abilities. Cyborg technology can help patients utilize artificial prosthetics for a better living by communicating with a robotic system. In space technology, AI can study orbital paths during successful launches and suggest actions based on its observations. Coming to Pharma Industry, AI is the future of pharma but the technology is available now. Artificial Intelligence can cut costs down, create new, effective treatments and above all else, help save lives. In terms of the industry's choice of patients for clinical trials, the software will also help companies detect any problems with drugs far earlier in terms of efficacy and safety. The industry therefore has a lot to gain from embracing solutions to AI and machine learning. It can be used to create a strong, sustainable pipeline of new medicines to good effect. Using the power of modern supercomputers and machine learning would make it possible for us to produce medicines faster and at reduced costs.

### ❖ Conclusion

In conclusion, the capability packages of AI in pharmacy can revolutionize the enterprise, presenting numerous benefits for both pharmacists and patients. From remedy management to drug discovery and persistent ailment management, AI generation can improve the accuracy and safety of medicine shelling out, accelerate the drug development manner, and help to enhance patient outcomes. The implementation of AI generation can also help to lessen healthcare prices via enhancing efficiency and reducing errors. however, it is critical to note that the implementation of AI in pharmacy additionally affords a few obstacles and challenges that want to be addressed. for example, there can be concerns around patient privateness and safety when using AI powered

systems to screen patient data. additionally, there can be a need for pharmacists to undergo additional training to correctly use and combine AI technology into their practice. nevertheless, with proper implementation and management, the benefits of AI in pharmacy a ways outweigh the potential obstacles and challenges, paving the manner for a brighter destiny in health care .even as the capacity programs of AI in pharmacy are good sized, there is nonetheless a great deal work that desires to be completed in terms of studies and development. One potential vicinity for destiny examine might be the combination of AI technology with other healthcare systems, which includes digital health records (EHRs) or telemedicine platforms. this can permit for a greater complete and coordinated technique to healthcare transport, improving affected person results and lowering healthcare charges. some other location for destiny studies could be the moral issues round the usage of AI technology in pharmacy. Addressing these issues in a considerate and proactive manner can help to make certain that the implementation of AI in pharmacy is each powerful and ethical. with the aid of continuing to discover those areas of look at, we can similarly release the capability of AI era in pharmacy and pave the way for a greater efficient and powerful healthcare system.

## ❖ References

- 1.Jackie Hunter. How artificial intelligence is the future of pharma. <https://www.drugtargetreview.com/article/15400/artificial-intelligence-drug-discovery/> (Accessed on November 23, 2019). (Accessed on November 23, 2019).
- 2.Flasinski M. Introduction to Artificial Intelligence. 1st ed. Switzerland: Springer International Publishing; 2016.p.4.
- 3.The Beginre's guide for AI 2019 Sep 13; <https://www.chapter247.com/blog/artificial-intelligence-beginners-guide/> (Accessed on November 23, 2019).
- 4.Shapiro SC. Artificial intelligence. Encyclopedia of Artificial intelligence, Vol. 1, 2ndedn. New York; Wiley 1992.
- 5.Rachel Brazil. Artificial Intelligence: will it change the way drugs are discovered? The Pharmaceutical Journal. 2017Dec 7; 299(7908) online DOI: 10.1211/PJ.2017.20204085
- 6.Topol, E.J. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019 Jan 7; 25:44–56.doi:10.1038/s41591-018-0300-7
- 7.Moosavi-Dezfooli S-M, Fawzi A, Fawzi O andFrossard P. Universal adversarial perturbations. IEEE Conference on Computer Vision and Pattern Recognition, Hawaii, 21–26 July 2017.
- 8.Khan O, Yadav AK, Khan ME, Parvez M. Characterization of bioethanol obtained from Eichhornia Crassipes plant; its emission and performance analysis on CI engine. Energy Sources, Part A Recovery, Util Environ Eff. 2019;43:1–11.

- 9.Motulsky A, Nikiema JN, Bosson-Rieutort D. Artificial intelligence and medication management. In: Househ M, Borycki E, Kushniruk A, eds. Multiple Perspectives on Artificial Intelligence in Healthcare. Lecture Notes in Bioengineering. Cham: Springer; 2021. [https://doi.org/10.1007/978-3-030-67303-1\\_8](https://doi.org/10.1007/978-3-030-67303-1_8).
- 10.Khan O, Khan MZ, Ahmad N, Qamer A, Alam MT, Siddiqui AH. Performance and emission analysis on palm oil derived biodiesel coupled with Aluminium oxide nanoparticles. Mater Today Proc. 2019;46
- 11.Howari H, Parvez M, Khan O, Alhodaib A, Mallah A, Yahya Z. Multi-Objective optimization for ranking waste biomass materials based on performance and emission parameters in a pyrolysis process—an AHP–TOPSIS approach. Sustainability. 2023;15(4):3690. <https://doi.org/10.3390/su15043690>.
- 12.Del Rio-Bermudez C, Medrano IH, Yebes L, et al. Towards a symbiotic relationship between big data, artificial intelligence, and hospital pharmacy. J of Pharm Policy and Pract. 2020;13:75. <https://doi.org/10.1186/s40545-020-00276-6>.
- 13.Zhavoronkov A, Vanhaelen Q, Oprea TI. Will artificial intelligence for drug discovery impact clinical pharmacology? Clin Pharmacol Ther. 2020;107:780–785.
- 14.Chethan Kumar GN. Artificial Intelligence: Definition, Types, Examples, Technologies. <https://medium.com/@chethankumargn/artificial-intelligence-definition-types-examples-technologies962ea75c7b9b> (Accessed on November 23, 2019).
15. Agatonovic-Kustrin S, Beresford R. Basic concepts of artificial neural network (ANN) modeling and its application in pharmaceutical research. J Pharm Biomed Anal 2000;22:717-27.
- 16.Baxt WG, Skora J. Prospective validation of artificial neural network trained to identify acute myocardial infarction. Lancet1996; 347: 12–5.
- 17.Nic Fleming. How artificial intelligence is changing drug discovery. Nature 557, S55-S57 (2018) doi: 10.1038/d41586-018-05267-x .
- 18.<https://www.digitalauthority.me/resources/artificial-intelligence-pharma/> (Accessed on November 23, 2019).
- 19.[https://www.himssanalytics.org/sites/himssanalytics/files/2017\\_Essentials%20Brief\\_Mobile\\_SNAPSHOT%20REPORT.pdf](https://www.himssanalytics.org/sites/himssanalytics/files/2017_Essentials%20Brief_Mobile_SNAPSHOT%20REPORT.pdf) (Accessed on November 23, 2019).
- 20.Keshavan M. Berg: Using Artificial Intelligence for Drug Discovery. <http://www.medcitynews.com/2015/07/berg-artificialintelligence/> (Accessed on November 23, 2019).
- 21.Cattell J, Chilukuri S, Levy M. How big data can revolutionize pharmaceutical R and D. 2013 Apr. <https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/how-big-data-can-revolutionize-pharmaceutical-r-and-d> (Accessed on November 23, 2019).
- 22.Ozerov IV, Lezhnina KV, Izumchenko E et al. In silico Pathway Activation Network Decomposition Analysis (iPANDA) as a method for biomarker development. Nature Commun, online 16 November 2016.

23. Keshavan M. Berg: Using Artificial Intelligence for Drug Discovery. <http://www.medcitynews.com/2015/07/berg-artificialintelligence/>. (Accessed on November 23, 2019).
24. M Stopford, M Myszczyńska, N Markus, D Sheppard, P Richardson, A Phelan, R Mead, L Ferraiuolo. C29 Harnessing machine learning and artificial intelligence to identify novel ALS therapeutics. (2017) Sessions 1 - 11, Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration, 2017 Nov 7;18(2):1- 73, DOI: 10.1080/21678421.2017.1368577 .
25. <https://blog.benchsci.com/6-things-we-learned-about-artificial-intelligence-in-drug-discovery-from-330-scientists> (Accessed on November 23, 2019).
26. Startups Using AI in Drug Discovery. <https://blog.benchsci.com/startups-usingartificial-intelligence-in-drug-discovery> (Accessed on November 23, 2019).
27. Bajorath J, Kearnes S, Walters WP, Georg GI, Wang S. The Future Is Now: Artificial Intelligence in Drug Discovery. *Journal of Medicinal Chemistry* 2019 62 (11), 5249-5249. DOI: 10.1021/acs.jmedchem.9b00805.
28. IDC study, "Data Age 2025," sponsored by Seagate, April 2017
29. Khedkar P, Mitra S. Boosting Pharmaceutical Sales and Marketing with Artificial Intelligence. <https://www.zs.com/Publications/Articles/Boosting-Pharmaceutical-Sales-and-Marketing-WithArtificial-Intelligence> (Accessed on November 23, 2019). 36. AI and pharma sales. *Pharma Times* online. 28th March 2019.
30. AI and pharma sales. *Pharma times* online. 28<sup>th</sup> march 2019. [http://www.pharmatimes.com/web\\_exclusives/ai\\_and\\_pharma\\_sales\\_1282806](http://www.pharmatimes.com/web_exclusives/ai_and_pharma_sales_1282806).