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ARTIFICIAL INTELLIGENCE IN PHARMACY: ENHANCING EFFICIENT DATA PROCESSING AND HEALTHCARE SOLUTIONS

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ABSTRACT

An important development in data processing and medical solutions is the use of artificial intelligence (AI) in pharmacy. This technology is changing the pharmaceutical industry by improving patient management, drug development, and discovery. Large-scale dataset analysis is made possible by AI techniques like machine learning and natural language processing, which increase productivity and lower expenses. Algorithms enhance clinical trial results, patient safety, and adherence, while AI's predictive analytics capabilities support personalized treatment. Notwithstanding these advantages, issues like algorithmic bias, data privacy, and the requirement for regulatory compliance still need to be resolved. With ongoing technological developments, interdisciplinary partnerships, and ethical considerations aimed at enhancing patient care and operational effectiveness in healthcare, the future of AI in pharmacy appears bright.

KEYWORDS: Artificial intelligence, Drug discovery, Drug delivery research, Hospital pharmacy, Drug adherence and dosage, Challenges to adoption of AI in pharma industry.

INTRODUCTION

A subfield of computer science known as artificial intelligence (AI) studies intelligent machines that solve issues through symbolic programming. It has been actively engaged in the science of issue solutions by applying pharmaceutical engineering and occupational health care.[1] The outcomes of artificial intelligence are comparable to those of human attentional processes.[2] Typically, this approach entails creating effective systems that use acquired data or training data, exhibit explicit or approximate fusion, and self-correction/adaptation.[3] The primary goal of artificial intelligence in pharmacy is to evaluate challenges related to efficient

data processing and provide abstract solutions. In mathematics, this type of calculation is referred to as a method and is equivalent to a theorem.[4] Machine learning that replicates specific cognitive activities is analyzed by artificial intelligence.[5] The employment of artificial intelligence technologies allows for more thorough analysis and insightful interpretations. This viewpoint blends computational intelligence in artificial technology with a number of practical static models. AI is a rapidly developing technology that is being used in many facets of industry and daily life. The pharmaceutical industry has recently found innovative and creative methods to apply this potent technology to address some of the most pressing issues it is currently facing.

The use of automated algorithms to tasks that have historically required human intelligence is known as artificial intelligence in the pharmaceutical sector. The way scientists create new medications and combat disease has changed over the last five years due to the application of artificial intelligence in the biotech and pharmaceutical sectors[6] Predicting in vivo reactions, therapeutic agent pharmacokinetic properties, suitable dosages, and other aspects is also made possible by the application of artificial intelligence models. The application of in silico models promotes drug efficacy and cost-effectiveness, which is consistent with the significance of drug pharmacokinetic prediction. research on drugs. Developments in artificial intelligence fall into two major categories. The first is conventional computer techniques that use expert systems that can both motivate people and demonstrate conclusions that can be derived from fundamental ideas. In the second, an artificial neutral network is implied, which can be used to represent how the brain functions.[7]

Robotics and automation are frequently used interchangeably with artificial intelligence (AI), usually referred to as machine intelligence. While artificial intelligence (AI) refers to the

presentation of human-like behavior and intelligence through computers or robots, robotics is merely the creation of machines capable of doing challenging and repetitive activities.[8] Historically, robots were not constructed with this "intelligent ability," but through a process called automation, they are able to move and carry objects on their own by using surface sensors and specially designed programming. In essence, artificial intelligence (AI) is a field of computer science that aims to build intelligent machines that can carry out jobs that humans typically undertake.[9]

- **History of artificial intelligence**

The beginnings of artificial intelligence (AI) can be traced back to myths, tales, and rumours of man- made animals granted intelligence and consciousness by talented artisans. Philosophers who attempted to define the human mind as the mechanical manipulation of symbols laid the framework for modern AI. In the 1940s, this research resulted in the development of the programmable computer. This device is an abstract depiction of mathematical reasoning. Several scientists have been inspired by this device and the concepts that underpin it to seriously investigate the feasibility of developing an electronic brain. The field of artificial intelligence study was established in the summer of 1956 during a workshop conducted on the campus of Dartmouth College in the United States.[10] The leading minds in AI research will remain participants for decades to come. In just one generation, many of them received millions of dollars to achieve their objective of building computers as intelligent as people.[11]

According to statistics, the natural language processing business, which includes a wide range of appliances such as text prediction, voice, and speech recognition, increased by 28.5% in 2017. Big data and business analytics generated $122 billion in global revenue in 2015, and the figure is expected to exceed $200 billion by 2020. The first examples of artificial intelligence appeared in the 1950s. He was once seen as a field for daydreamers, but this began to change in 1997, when IBM's Deep Blue computer defeated world chess champion Garry Kasparov. In 2011, IBM's new supercomputer Watson won a $1 million prize on the US quiz show Jeopardy.

Since then, Watson has strengthened its involvement in healthcare and medication research, including a 2016 collaboration with Pfizer to accelerate immuno-oncology drug development. In December 2016, IBM teamed with Pfizer to create IBM Watson, a cloud-based medical laboratory reporting platform that enables researchers to detect links across disparate datasets

using dynamic visualizations.

➢ **Objectives of AI[12]**

Creation of Expert: Systems It comprises the creation of intelligently acting automated systems that advise humans on the optimal course of action.

Implementation of Human Intelligence in Computers[13]: As a result, computers will establish similar cognitive patterns that will allow them to act like people and make the proper choices in the face of difficult situations. This will reduce the workload for humans by enabling automated activities through the use of algorithms.

Multi-Domain Application: AI will be useful in a variety of domains, including computer science, cognitive science, statistics, psychology, engineering, ethics, the natural sciences, healthcare, space technology, logic, and linguistics.

Applications in Computer Science: AI is used to develop a variety of mechanisms, including search and optimization, logic, control theory, language analysis, neural networks, classifiers, statistical learning methods, and probabilistic methods for uncertain reasoning, in order to address a wide range of challenging issues in computer science**.**

➢ **Advantages[14]**

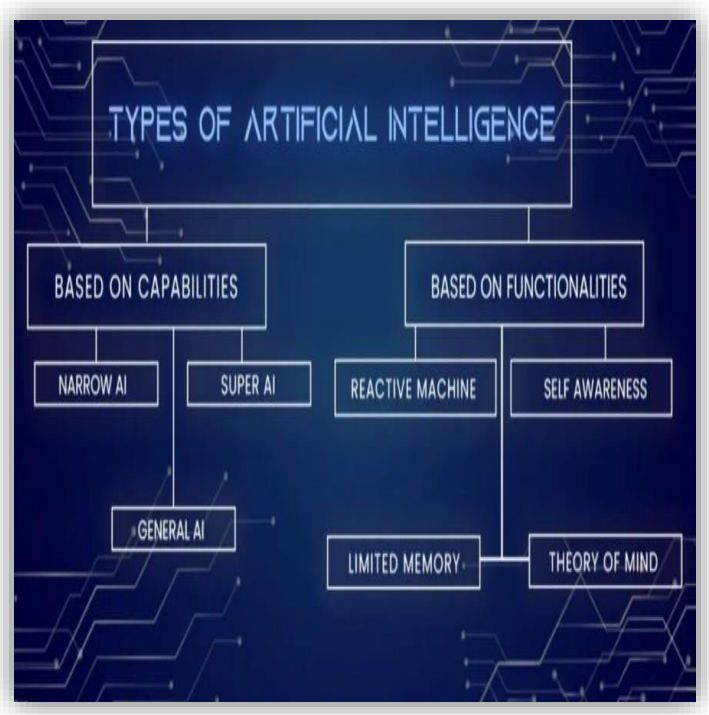
- Artificial intelligence now enables pharmaceutical companies to address difficulties beyond traditional data analysis.
- AI can do specific tasks with greater accuracy, resulting in decreased costs and more production.
- AI offers valuable insights to improve clinical study outcomes.
- Strong understanding of market dynamics, consumer behavior, and their interactions.
- It aids in patient selection for clinical trials and early detection of drug efficacy and safety concerns.
- It improves antiviral detection performance and promotes AI algorithm development. Additionally, it aids in patient selection for clinical trials.
- If AI is properly constructed, it will make fewer mistakes than humans. They would be extremely fast, accurate, and precise.
- Robotic surgery will provide greater precision than human surgery.
- Deep learning and natural language processing allow AI to analyze vast volumes of

biological data, revolutionizing drug discovery.

➢ **Disadvantages**[14]

- Since AI can't think for itself and can only follow instructions, it mostly lacks human touch.
- It is effective in corrupting the next generation.
- Can be adjusted to mass destruction first.
- If robots begin to replace humans in all occupations, unemployment will result.
- Can be expensive to construct, maintain, and reconstruct.
- When used improperly, machines may quickly cause devastation. At the very least, many people dread that.
- Humans are dependent on AI and lose their mental faculties, as has already been partially observed with cellphones and other technology.
- AI as robots has the potential to surpass humans and enslave humanity

➢ **Type of Artificial Intelligence**



A. Based on the caliber and their presence

1. Artificial narrow intelligence or weak AI
2. Artificial general intelligence or strong AI
3. Artificial super intelligence[15]

B. Based on presence /Functionalities (Four Primary Artificial Intelligence Type)

1. Reactive machine
2. Limited memory system
3. Theory of mind
4. Self-awareness

A. Based on the calibre and their presence

A1. Artificial Narrow Intelligence (ANI) or Weak AI: It focuses on certain activities, including facial recognition, driving, chess, and traffic light management.[16]

A2. Artificial General Intelligence (AGI) or Strong AI: It is frequently referred to as human-level AI and is capable of mimicking human abilities. AI of this kind can expedite human cognitive processes and manage new activities.

A3. Artificial Super Intelligence (ASI): In comparison to what is already accessible and what is still being developed, it outsmarts humans and demonstrates noticeably higher activity in domains like sketching, arithmetic, and space-related tasks.[17]

B. Based on presence (Four Primary Artificial Intelligence Type)

B1. Reactive Machine: Because it lacks a memory system, it can only be used for specialized, one- purpose purposes and is unable to draw on prior experiences. Reactive machines are the name given to this category. IBM's chess program, which can recognize chessboard pieces and make predictions, is a notable example of one of these systems.

B2. Limited memory system: It has a limited memory system that uses prior knowledge to solve a number of problems. With regard to self-driving cars, this The system may effectively make decisions using recorded observations that are applied to later acts, but These documents are not kept on file indefinitely.

B3. Theory of mind: It is based on the idea of the "Theory of Mind," which holds that each person's distinct ideas, intentions, and wants have an impact on their decision-making. There are currently no AI systems of this type.

B4. Self-awareness: It possesses self-awareness and self-consciousness. However, such an AI system does not now exist.[17]

➢ ***TOOLS OF AI***

- **Robot pharmacy**

To improve patient safety, the UCSF Medical Center uses robotic technology for medication manufacturing and monitoring. They assert that 3,50,000 doses of medication have been

precisely prepared by the machine. The robot's size and ability to precisely deliver medications have been demonstrated to be far superior to those of humans. One application of robotic technology is the production of dangerous chemotherapy drugs for injection and oral usage. With greater autonomy, the UCSF nurses and pharmacists can now concentrate on direct patient care and teamwork with the physicians, maximizing their expertise.[18]

- **MEDi Robot:** MEDi stands for medicine and engineering designing intelligence AI-powered instruments The pain management robot was developed under the direction of Tanya Beran, a professor of community health sciences at the University of Calgary in Alberta. She came up with the idea after working in hospitals where kids cry while receiving treatment. By first building a relationship with the children and then describing what to expect during a medical treatment, the robot can be made to appear to have artificial intelligence (AI) even if it is incapable of thinking, planning, or reasoning.[19] [20]

- **Erica robot:** The new care robot Erica was developed in Japan by Hiroshi Ishiguro, a researcher at Osaka University. It was developed in collaboration with the Japan Science and Technology Agency (ATR), Advanced Telecommunications Research Institute International, and Kyoto University. Its facial characteristics blend European and Asian features, and it speaks Japanese.[21]

- **TUG robots:** Aethon TUG robots are designed to walk throughout the hospital on their own and carry resources, prescription drugs, meals, specimens, and big items like trash and linen. For carrying racks, bins, and carts, it comes in two varieties: permanent and secured carts and an interchangeable base platform.[22]

- **Berg:** Berg, a biotech business based in Boston, is one of the top companies utilizing AI I its many operations. Using a large patient database and an AI-based drug discovery platform, it finds and validates the numerous disease-causing biomarkers before selecting treatments based on the information gathered.[23]

➢ ***APPLICATION OF ARTIFICIAL INTELLIGENCE IN PHARMA INDUSTRY***

Integrating Al systems into pharmaceutical procedures can improve efficiency, cost-effectiveness, and ease of use. Furthermore, because Al systems are designed to learn from fresh data and experience on a constant basis, they can be an effective tool in the pharmaceutical industry's R&D. AI has numerous applications in the pharmaceutical

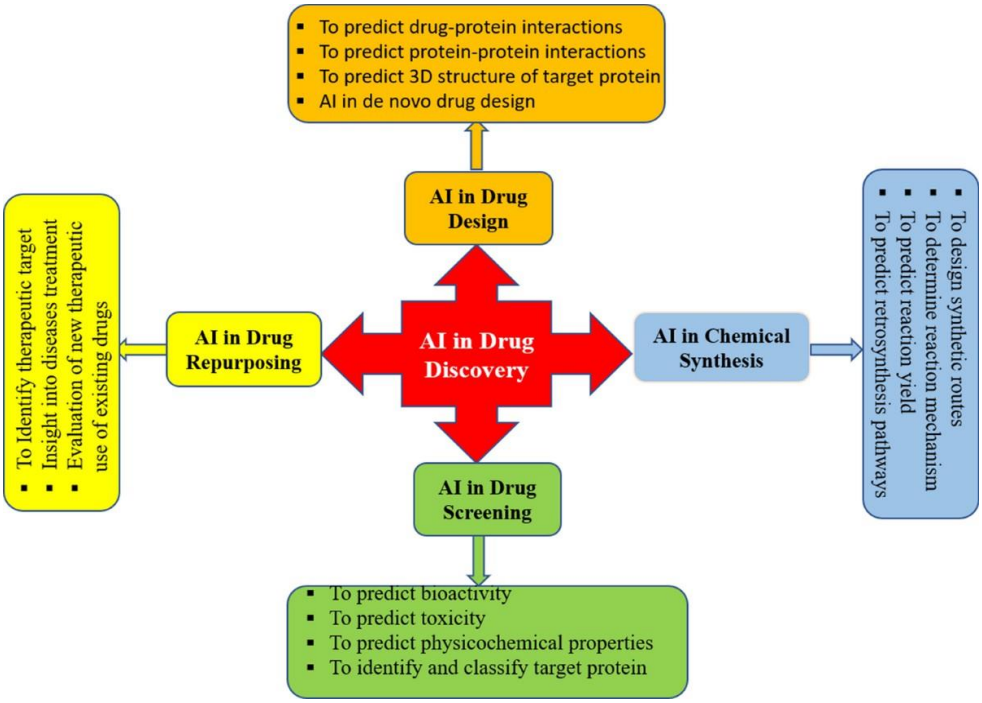
business, including medication discovery, research, production, and marketing.

1. Research & Development

To speed up the drug discovery process, multinational pharmaceutical corporations are utilizing advanced machine learning (ML) and artificial intelligence (AI) technologies. These clever technologies are helpful in tackling issues pertaining to intricate biological networks because they are designed to identify intricate patterns in sizable datasets. This feature is excellent for examining the trends of various illnesses and determining which medicine combinations will work best to address specific characteristics of a particular illness. Pharmaceutical firms can then devote resources to the study and creation of these medications that are most likely to be successful in curing an illness or other medical problem.[24]

2. Drug Discovery Process and Design

In the pharmaceutical sector, artificial intelligence (AI) is being used more and more for drug discovery and design. The discovery of new biological targets is Al's responsibility. Additionally, it is employed in the fields of biomarker identification and multi-target drug development, offering a highly efficient method with a high degree of The use of Al in drug testing shortens the time required to finish clinical studies and introduce goods to the market, which is one of the pharmaceutical industry's primary benefits. For example, pharmaceutical researchers can identify and validate new cancer medications using data from longitudinal EMR (Electronic Medical Records) records and other omic data.[25]



3. Drug Development

Al could contribute to the advancement of research and development. From creating and discovering novel compounds to target-based medication testing and Findings AI is capable of anything.[26]

Man-made artificial intelligence (AI) has the capacity to improve the The process of research and development (R&D) in a several methods, such as target-based medication discovery and validation, molecular design, and identity, among other things. Merely 13.8% of medications pass clinical testing, an MIT study claims. Research. Furthermore, a pharmaceutical business has to pay between US$ 2 million to US$ 161 million. billion to finish a drug's clinical trial procedure and obtain FDA clearance. These are the main reasons for the increasing usage of Al by pharmaceutical firms, which seek to reduce operating expenses, create more reasonably priced medications and therapies, and boost the success rates of new drugs.[24]

4. Diagnosis

The FDA has gave the go-ahead for Gl Genius, a medical device that utilizes machine learning and an Al algorithm to identify colon cancer symptoms. During a colonoscopy, this tool makes it simple for medical professionals to locate areas of the colon that may have lesions. The information recorded in EMRS can be used by ML systems to forecast medical conditions in real time, aid in diagnosis, and recommend therapies. . Machine learning (ML) technology is being used by healthcare providers worldwide to safely store private patient information in centralized storage systems or the cloud.

Physicians can view these documents, which are referred to as electronic medical records (EMRS), whenever necessary. To.[24] These days, a lot of work is being done to differentiate, extract, and provision theelatively using deep learning, brain systems management, and computation-based innovation. A significant amount of data was collected. Memory loss and cancer are the two primary illnesses where artificial intelligence has become more significant.[27]

5. Disease Prevention

Al can be used by pharmaceutical companies to discover cures for both common ailments like Parkinson's and Alzheimer's as well as unusual disorders. Because the return on investment (ROI) is so poor in comparison to the time and expense required to create pharmaceuticals for treating rare diseases, these businesses generally do not invest time and

money in researching therapies for uncommon diseases. According to Global Genes, there are currently no FDA-approved therapies or treatments for nearly 95% of uncommon diseases. But because to the inventive abilities of Al and ML, things are rapidly getting better.[24]

6. Epidemic Prediction

Artificial intelligence (AI) and machine learning (ML) are already widely used by pharmaceutical corporations and healthcare providers to monitor and forecast global epidemic outbreaks. These technologies make use of data gathered from multiple web sources, examine how diverse biological, environmental, and geological elements affect population health in various locations, and try to connect these aspects to previous epidemic outbreaks. These AI/ML models are especially useful in developing countries that lack the financial and medical infrastructure necessary to contain an epidemic. The ML-based malaria outbreak prediction model which acts as a warning system for malaria outbreaks and assists medical professionals in choosing the most effective course of action to combat it, is a good illustration of this.[24] AI and ML are already used by many pharma companies and healthcare providers to monitor and forecast epidemic outbreaks across the globel. These technologies use data collected from various online sources to analyze the relationship between geological, environmental, and biological factors and population health in various geographic locations. They also attempt to establish a link between these factors and past outbreaks of epidemics. Such AI/ML models become especially useful for underdeveloped economies that lack the medical infrastructure and financial framework to deal with an epidemic outbreak.[26]

7. Remote Monitoring

Remote monitoring is a major development in the healthcare and pharmaceutical sectors. Al techniques have already been used by a number of pharmaceutical companies to develop wearables that allow them to remotely monitor patients with life-threatening conditions. For instance, Tencent Holdings and Medopad have collaborated to create Al technology, which can remotely monitor Parkinson's disease patients and reduce the time needed to finish a motor function assessment from thirty to three minutes. This Al technology can be used with smartphone apps to remotely monitor a patient's opening and closing movements.[24] The pandemic, which brought about quick growth in the industry and illustrated the difficulties of remote care, brought to light the potential for Remote Patient Monitoring (RPM) devices to transform at-home care. The market for RPM devices is anticipated to grow to $760 million by 2030, according to a recent analysis by Global Data. Through remote consultations,

diagnosis, and treatment in non-emergency situations, technology is helping the healthcare sector increase efficiency and get beyond geographic constraints, according to the Thematic Research - Virtual Care and Telemedicine - 2023 research.[28]

8. Manufacturing

Pharma companies can use artificial intelligence (AI) to manage and enhance all aspects of the manufacturing process, including: Pharma companies can use Al to improve productivity, efficiency, and speed up the production of lifesaving drugs. Process automation, waste reduction, quality control, predictive maintenance, and Designed optimization.[24]

1. **Quality control:** Lowering the high attrition rate and failure rate, cutting paperwork, standardizing operating procedures with machine assistance, and raising quality standards with less experiment.[29]
2. Predictive Maintenance
3. Waste reduction
4. Design Optimization
5. Process automation

9. Marketing

Artificial intelligence (AI) can be a helpful tool in pharmaceutical marketing because the pharmaceutical sector is a sales-driven one. Pharmaceutical businesses can use Al to investigate and develop innovative marketing techniques that guarantee significant sales and brand recognition. Al can help with customer journey mapping, which helps businesses determine which marketing strategy brought in visitors (lead conversion) and convinced those people to buy from them. This makes it possible for pharmaceutical companies to focus more on marketing tactics that generate the most conversions and boost sales. In order to ascertain which marketing initiatives continued to yield the highest profits, Al Tools can also examine past campaigns and compare the outcomes. The pharmaceutical sector lacks the requisite expertise and abilities to integrate and utilize Al. However, these actions can help facilitate its acceptance.

- Collaborating with academic institutions focused on aluminum research and development to help pharmaceutical businesses use aluminum.
- Partnering with Al-driven medical discovery firms provides access to advanced technologies, industry knowledge, and expert assistance.
- Improve productivity by teaching R&D and manufacturing teams how to utilize and use

Al tools and procedures.[24]

10. Drug Adherence and Design

All of these are significant applications of artificial intelligence (AI) in the pharmaceutical industry. Al will surely speed up process automation and increase accuracy in the pharmaceutical and healthcare industries. Drug development and healthcare organizations will benefit from these Al trends and use cases in the pharmaceutical industry by assuring efficacy across end-to-end production lines and meeting FDA standards. Al is currently being utilized in pharmaceuticals to determine the appropriate dosages of drugs to guarantee the safety of drug users. It not only aids in patient monitoring throughout clinical trials, but it also recommends the appropriate dosage at regular intervals.[25]

AI in Healthcare Appliances

A well-known branch of computer science, artificial intelligence has the potential to improve human existence in a variety of ways. AI is capable of disease prevention, detection, diagnosis, and potentially treatment. Artificial intelligence is often utilized to cure serious illnesses like cancer, neurological disorders, diabetes, and heart disease. AI can identify issues and patient life hazards because of its high speed and precision. Nowadays, a subset of artificial intelligence called machine learning can help numerous individuals save their lives.[31] Artificial intelligence's cognitive powers make it a valuable tool for analyzing healthcare data. Artificial intelligence is being used in various medical fields, including cancer, neurology, and cardiology, as it continues to advance. Machine learning and deep learning, both subcategories of artificial intelligence, deal with structured healthcare data as well as unstructured datasets controlled by Natural Language Processing, among other things.[31] Researchers in Human-Computer Interaction have developed principles for safe and reliable AI-based interactions. These AI systems can be further improved by increasing the number of collaborations with various medical departments and organizations. Artificial intelligence- enabled healthcare appliances can analyze medical images as effectively as human doctors.[32]

➢ **Technologies used in AI[33]**

- **Natural language processing (NLP)**: instruct computers to process and examine a lot of data in natural language.
- **Support vector machine (SVM):** Given a set of labelled training examples, the method

generates an ideal hyperplane that classifies fresh cases.

- **Heuristics:** mental evasions that lessen the strain of decision-making. For instance, utilising a generalisation, a well-informed estimate, an estimation, profiling, or common sense.
- Artificial neural networks (ANN: An information processing model developed in the 1940s is based on how biological nervous systems, such as the brain, process information. A mathematical function is a synthetic neuron. In order to identify solutions, ANN use data samples rather than entire data sets, saving time and money. ANNs (PYTHON) consist of three linked layers. Neural networks, like the brain, learn new information using a feedback mechanism known as back-propagation. Self-driving cars, character recognition, image reduction, and stock market forecasting all use artificial neural networks (ANNs). Artificial neural network (ANN) software models brain neural network pattern recognition skills. The artificial neuron system collects data from multiple external sources, analyzes it, and makes decisions in the same way that a single neuron in the brain would. It's worth noting that ANN resembles adaptive biological neurons and the biological nervous system. ANN is a feasible modeling method, especially for data sets with non-linear connections, as found in pharmaceutical operations.

- **Area of Artificial Intelligence**

➢ **Language understanding**

the capacity to "understand," reply to spoken language in written form, translate from one natural language to another, and translate between two natural languages.

- Speech Recognit
- Processing Semantic Information (Computational Linguistics)
- Replying to inquiries
- Getting information back
- Translation of a language.

➢ ***FUTURE SCOPE OF ARTIFICIAL INTELLIGENCE***[26,23,34]

- AI used in science and research. AI in cyber security.
- AI in data analysis. AI in health care etc.
- AI in transport, AI in home.
- AI in academia and industry Science has made significant progress with AI. Large amounts of data can be handled by artificial intelligence, which can process information

more quickly than human brains. This makes it ideal for studies where the sources have large amounts of data. In this area, AI has already made strides.

AI in cyber security

Another area where AI is helpful is cybersecurity. As more companies shift their data to cloud and IT networks, the threat of hackers is increasing.

AI in transport

The transportation sector has been using AI for decades. Aircraft have been using autopilot to navigate while in the air since 1912. An autopilot system controls a plane's course, yet this technology is not unique to airplanes. Ships and spacecraft also utilize autopilot to help them stay on their desired course.

AI in data analysis

Artificial intelligence and machine learning have a big impact on data analysis. AI algorithms are capable of improving with each repeat, hence boosting accuracy and precision. Data analysts that work with large datasets can benefit from AI.

Challenges and Ethical Considerations

Integrating AI technologies in pharmacy practice and management presents ethical challenges, including ensuring patient safety, privacy, and equal access to healthcare services.[35]

Data Privacy and Security Concerns

The collecting, storage, and use of patient health data raises concerns regarding privacy and security. AI systems require secure access to sensitive patient data, such as medical histories, medications, and lab results, to prevent unauthorized access, breaches, and misuse. Compliance with data protection requirements such as HIPAA and GDPR, as well as the implementation of effective cybersecurity measures, are critical for protecting patient confidentiality and preventing data breaches.[35]

Algorithmic Bias and Fairness

The precision and equity of AI-driven clinical decision support systems, drug recommendations, and patient care interventions might be impacted by biases pertaining to race, ethnicity, gender, and socioeconomic position. In order to eliminate biases and guarantee equitable healthcare delivery, addressing algorithmic bias necessitates transparent

model creation, varied and representative training data, and continuous monitoring and evaluation of AI systems.[36]

Interoperability and Data Exchange

Interoperability between AI systems and existing healthcare IT infrastructure, including EHRs and PIS, poses technological problems in data sharing, integration, and standardization. Incompatible data formats, proprietary software systems, and isolated data repositories all impede seamless communication and interoperability between AI platforms and healthcare systems, reducing the usability and effectiveness of AI-powered solutions. To integrate AI into pharmacy practice, it's crucial to develop interoperability standards, use open-source technologies, and promote data sharing programs.[37]

Regulatory and Legal Compliance

There are difficulties navigating the legal and regulatory frameworks that control the application of AI in healthcare, including issues with accountability, liability, and compliance. To guarantee patient safety and regulatory compliance, AI-driven clinical decision support systems, drug algorithms, and predictive analytics models must abide by quality standards, ethical principles, and regulatory criteria. To reduce legal risks, liability issues, and guarantee accountability for AI-driven intervention, clear criteria are required for the validation, certification, and use of AI systems in pharmacy practice.[38]

Healthcare Workforce Training and Education

In order to successfully use and incorporate AI-driven solutions into daily workflows, pharmacists, healthcare professionals, and support workers must get upskilling and training. To provide pharmacists with the abilities and information required to use AI technology for medication administration, clinical decision-making, and patient care, training programs should emphasize digital health competencies, data analytics, and AI literacy. To give the healthcare professionals the skills they need to fully utilize AI in pharmacy practice, investments in professional development programs and ongoing education are crucial.[39]

Patient Autonomy and Informed Consent

AI interventions in pharmacy practice bring ethical considerations related to patient autonomy, informed consent, and collaborative decision-making. AI technology employed in drug management, clinical decision support, and healthcare delivery may not be well understood by patients, leading to concerns about transparency, accountability, and

empowerment. In the age of AI-driven healthcare, it is critical to ensure informed consent, respect patient choices, and promote shared decision-making procedures to maintain patient autonomy, develop trust, and foster collaborative partnerships between patients and healthcare providers.[40]

Social and Ethical Implications of AI

AI technologies in healthcare have significant social and ethical consequences, including equity, justice, and societal effect, that must be carefully considered and reflected upon. AI interventions may worsen healthcare disparities, inequities, and the digital gap, especially among marginalized and impoverished communities. Ethical frameworks, stakeholder engagement, and community participation are important to address social determinants of health, promote health equity, and ensure that AI technologies benefit all parts of society.[40]

Professional and Ethical Responsibilities of Pharmacists

When using AI technology in pharmacy practice, pharmacists have ethical and professional obligations to protect patient safety, privacy, and treatment quality. The ethical application of AI algorithms, patient data protection, and preserving professional autonomy and judgment can all provide ethical conundrums. When using AI-driven technologies, pharmacists must abide by professional standards, codes of conduct, and ethical guidelines to make sure that AI-driven therapies respect patient autonomy, promote patient well-being, and are consistent with ethical principles.[41]

Societal Trust and Acceptance

Transparency, accountability, and public involvement are necessary to increase society trust and acceptance of AI in healthcare. The accuracy, fairness, and dependability of AI-powered clinical decision support systems, drug algorithms, and predictive analytics models may raise questions for patients, healthcare professionals, and legislators. Building trust, encouraging acceptance, and promoting the responsible use of AI in pharmacy practice all depend on including stakeholders in conversations about the advantages, dangers, and constraints of AI technology and requesting opinions and comments from a range of viewpoints.[41]

- **Future Directions and Opportunities**

As AI continues to evolve and mature, it presents numerous opportunities for innovation, collaboration, and transformation in pharmacy practice and management. Future directions in the integration of AI technologies hold the potential to revolutionize medication management,

improve patient outcomes, and advance pharmaceutical services.[42]

Future directions

AI-enabled Personalized Medicine

Personalized pharmaceutical therapy management based on each patient's unique traits, genetic profile, and response to treatment is becoming possible because to developments in AI-driven genomics, pharmacogenomics, and precision medicine. The creation of predictive modeling algorithms to optimize medication selection, dosage schedules, and therapeutic interventions based on patient-specific characteristics, such as genetic polymorphisms, biomarker profiles, and clinical phenotypes, is one of the future paths in AI-enabled personalized medicine.[42]

Real-time Prescription Monitoring and Intervention

Real-time surveillance systems that identify mistakes, adverse reactions, and drug interactions at the point of service may be a part of AI-powered prescription monitoring. Preventive interventions and the reduction of medication-related hazards are made possible by AI algorithms that analyze prescription data, patient health records, and clinical guidelines to provide pharmacists and other healthcare professionals with real-time alerts, recommendations, and decision assistance.[42][43]

Integration of AI with Digital Health Technologies

AI integration with digital health platforms, wearables, and mobile apps can improve medication adherence, remote patient monitoring, and self-management of chronic illnesses. AI-powered virtual assistants, chatbots, and conversational agents can provide individualized

pharmaceutical education, counseling, and support to patients, improving self-care and empowering them to manage their health and drugs effectively.[44]

AI-driven Drug Discovery and Development

New drug candidates can be found more quickly, therapeutic targets can be optimized, and the drug development pipeline can move more quickly thanks to developments in AI-driven drug discovery and development. In order to address unmet medical needs and advance precision medicine approaches, future directions include the use of AI-enabled predictive modeling, virtual screening, and de novo drug design techniques to design and optimize drug molecules with improved potency, selectivity, and safety profiles.[45]

Blockchain Technology for Drug Traceability and Supply Chain Transparency

There are chances to improve drug traceability, supply chain transparency, and counterfeit drug identification in pharmacy operations by combining blockchain technology with AI-driven supply chain management systems. In the future, blockchain-based decentralized ledgers will be used to monitor and confirm the pharmaceutical items' legitimacy, expedite legal compliance, and improve patient safety by making sure the consistency of the pharmaceutical supply chain from production to distribution.[45]

AI-driven Clinical Trials Design and Patient Recruitment

New cures and treatments could be developed more quickly thanks to developments in AI-driven clinical trial design and patient recruitment, which could also enhance trial protocols and find appropriate patient cohorts. The use of AI-enabled predictive modeling, patient matching algorithms, and real-world data are some potential future avenues. analytics to increase patient retention, expedite clinical trial recruitment, and boost productivity and cost-effectiveness of clinical studies in the practice of pharmacy.[46]

Augmented Reality (AR) and Virtual Reality (VR) for Pharmacy Education and Training

Opportunities to improve pharmacy education, training, and simulation-based learning experiences are presented by the combination of AR and VR technologies with AI-driven learning platforms.

Future directions include creating immersive AR/VR environments for pharmaceutical compounding, medication counseling, and clinical simulations. These will allow pharmacy

practitioners and students to practice techniques, obtain practical experience, and improve clinical competency in a virtual environment.[47]

Collaboration and Interdisciplinary Research

Future directions in the integration of AI in pharmacy practice and management involve collaboration and interdisciplinary research across academia, industry, and healthcare organizations. Opportunities exist for crossdisciplinary partnerships between pharmacists, computer scientists, data scientists, and biomedical engineers to develop innovative AI-driven solutions, conduct translational research, and address complex healthcarechallenges, such as medication adherence, medication safety, and medication management in diverse patient populations.[48]

Regulatory Frameworks and Policy Development

Future directions for AI technology development include creating standards, rules, and regulatory frameworks to control the ethical application of AI in pharmacy administration and practice.

In order to guarantee the safety, effectiveness, and moral application of AI-driven interventions to improve patient care outcomes and pharmaceutical services, policymakers, regulatory bodies, and professional associations have the opportunity to create guidelines for AI validation, certification, and deployment in healthcare settings.[49]

Continuous Learning and Professional Development

Pharmacists and healthcare professionals must continuously study and develop to stay up-to-date on AI trends, best practices, and ethical considerations. Future directions include investing in ongoing education, training, and lifetime learning. endeavors to provide pharmacists with the skills, knowledge, and competences required to leverage the potential of AI technology in pharmacy practice and management, therefore enabling the delivery of high-quality, patient-centered Care in the Digital Age.[37]

CONCLUSION

In conclusion, artificial intelligence (AI) in pharmacy has shown significant potential in improving patient care, drug discovery, and healthcare solutions. The use of AI in pharmaceutical industries has already brought about advancements in drug development, patient monitoring, and personalized treatment. However, challenges such as algorithmic bias,

data privacy concerns, and regulatory compliance need to be addressed. AI tools like robotics, AI-powered robots like MEDi, and TUG robots are already being used in healthcare settings to enhance patient safety and medication delivery. The future of AI in pharmacy looks promising with opportunities for personalized medicine, real-time monitoring, drug discovery, and supply chain transparency. Collaborations between various stakeholders, continuous learning, and ethical considerations are essential for the successful integration of AI in pharmacy practice. The top pharmaceutical companies utilizing AI like.

AstraZeneca, Pfizer, and Roche are leading the way in leveraging AI technology to transform the pharmaceutical industry. As AI continues to evolve, the future of pharmacy practice will be shaped by innovations, interdisciplinary research, and advancements in AI technology aimed at improving patient outcomes and revolutionizing healthcare services.

REFERENCE

1. Dasta, J. F. Application of artificial intelligence to pharmacy and medicine. *Hospital pharmacy*, 1992; *27*(4): 312-5.
2. Mak KK, Pichika MR. Artificial intelligence in drug development: Present status and future prospects. Drug Discov Today, 2019; 24(3): 773-80.
3. Hassanzadeh P, Atyabi F, Dinarvand R. The significance of artificial intelligence in drug delivery system design. Adv Drug Deliv Rev., 2019; 151: 169-90.
4. Duch W., Swaminathan K., Meller J., Artificial Intelligence Approaches for Rational Drug Design and Discovery. Current Pharmaceutical Design, 2007; 13: 00.
5. Russel S, Dewey D, Tegmark M. Research priorities for robust and beneficial artificial intelligence. AI Mag., 2015; 36(4): 105-14.
6. Krishnaveni, C., Arvapalli, S., & Sharma, J. V. C. Artificial intelligence in pharma industry-a review. International Journal of Innovative Pharmaceutical Sciences and Research, 2019; *7*(10): 37-50.
7. Das, S., Dey, R., & Nayak, A. K. Artificial Intelligence in Pharmacy. Indian Journal of Pharmaceutical Education and Research, 2021; 55(2): 304-318.
8. Honavar, V., Artificial intelligence: An overview. Artificial Intelligence Research Laboratory, 2006; 1-14.
9. Lopes, V. and L.A. Alexandre, An overview of block chain integration with robotics and artificial intelligence, 2018; arXiv preprint arXiv: 1810.00329.
10. Kaplan, A., & Haenlein, M. Siri, Siri, in my hand: Who"s the fairest in the land? On the

interpretations, illustrations, and implications of artificial intelligence. *Business horizons*, 2019; *62*(1): 15- 25.

11. Friendly, A. I. History of artificial intelligence. *golden years*, 1974; *1956*: 3-1.
12. Silver D, Schrittwieser J, Simonyan K. Mastering the game of Go without human knowledge. Nature, 2017; 550: 354–359.
13. Moosavi-Dezfooli S-M, Fawzi A, Fawzi O and Frossard P. Universal adversarial perturbations. IEEE Conference on Computer Vision and Pattern Recognition, Hawaii, July 2017; 21–26.
14. SHARMA, Tamanna, et al. Artificial intelligence in advanced pharmacy. International Journal of Science and Research Archive, 2021; 2.1: 047054.
15. https://www.genengnews.com/gen-edge/covid-19-puts-spotlight-on-artificial-intelligence/
16. Jiang F, Jiang Y, Zhi H, Artificial intelligence in healthcare. Past, present and future, Stroke Vasc neurol, 2017; 2(4): 230-243.
17. 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(5): 717- 27.
18. University of California San Fransisco. New UCSF Robotic Pharmacy Aims to Improve Patient Safety. Available from: https://www.ucsf.edu/ news/2011/03/9510/new-ucsf-robotic-pharmacyaimsimprove-patient-safety. [Last Accessed on 2017 Jun 24.
19. McHugh R, Rascon J. Meet MEDi, the Robot Taking Pain Out of Kids‟ Hospital Visits. Available from: http:// www.nbcnews.com/news/us-news/meet-medi-robottaking-pain-out-kidshospital-visits- n363191. [Last accessed on 2017 Jun 24
20. Trynacit K. MEDi Robot to Comfort Patients in Stollery Children‟s Hospital. Available from: http://www.cbc. ca/news/canada/edmonton/medi-robot-to-comfortpatients-in-stollery-children- shospital-1.3919867. [Last accessed on 2017 Jun 24].
21. Eye for Pharma. Artificial intelligence- A Brave New World for Pharma Available from: . https://www.social.eyeforpharma.com/clinical/artificial-intelligence-brave-new-worldpharma. [Last accessed on 2017 Jun 24].
22. McCurry J. Erica, „most intelligent‟ Android, Leads Japan's Robot Revolution. Available from: http:// www.thehindu.com/todays-paper/tp-national/ Erica-%E2%80%98mostintelligent%E2%80%99-android-leads-Japan%E2%80%99s-robot-revolution/ article13974805.ece [Last accessed on 2017 Jun 24]. Aethon. TUG robots. Available from: http://www.aethon. com/tug/tughealthcare/. [Last accessed on 2017 Jun.
23. Feng R., Badgeley M., Mocco J., et al., J Neurointerv Surg, 2018; 10(4): 358-362.

24. Application of ai in pharma industry https://www.upgrad.com/blog/artificialintelligence-in- pharmaceutical-industry/
25. https://usmsystems.com/artificialintelligence-in-pharma/
26. Nagaravi kiran T, Suresh kumar N, Lakshmi GVN, Naseema S, Bhargav SB Scholar Research and Library, ISSN : 0974-5071, Der Pharmacia Lettre, 2021; 13(5): 06-14.
27. Vasim Mansur Aparadh, Nitin Chandrakant Mohire, Gita Nitin Mohire Ritesh Kumar, Abhijit Anil Gaikwad, Ravindra Bhimraj Laware, Tapan Kumar Mahato, Anagha Amit arvadnya. DOI:10.48047/ecb/2023.12.Si11. 044.Eur. Chem. Bull., 2023; 12(11): 558-572.
28. Eve Thomas, September 15 2023 https://www.pharmaceuticaltechnology.comnews/remote-patient-monitoring-market-willre Ach-760m-by-2030/?cf-view&cfs closed
29. Dnyaneshwar Kalyane, Gaurav Sanap, Debleena Paul, Snehal Shenoy, Neelima Anup, Suryanarayana Polaka, Vishakha Tambe and Rakesh K. Tekade. The Future of Pharmaceutical Product Development and Research DOI:https://doi.org/10.1016/B978- 0-12-814455-8.00003-7
30. Davies, H. C., Eynon, R., & Salveson, C. The mobilisation of AI in education: A Bourdieusean field analysis. Sociology, 2021; 55(3): 539-560.
31. Ding, H., Gao, R. X., Isaksson, A. J., Landers, R. G., Parisini, T., & Yuan, Y. State of AIbased monitoring in smart manufacturing and introduction to focused section. IEEE/ASME Transactions on Mechatronics, 2020; 25(5): 2143-2154.
32. Husbands, P., Harvey, I., Cliff, D., & Miller, G. Artificial evolution: A new path for artificial intelligence? *Brain and cognition*, 1997; *34*(1): 130-159.
33. Sutariyaa V, Grosheva A, Sadanab P, Bhatia D, Pathaka Y. Artificial neural network in drug delivery and pharmaceutical research. The Open Bioinformatics Journal, 2013; 7(1,M5): 49-62.
34. Davatzikos C., Neuroimage, 2019; 197: 652–656. https://doi.org/10.1016/j.neuroimage.2018.10.003
35. Nabile M. Safdar a c, John D. Banja b f, Carolyn C. Meltzer Ethical considerations in artificial intelligence https://www.sciencedirect.com/journal/european-journal-of radiology/vol/122/suppl/C.
36. Jason Borenstein, Ayanna Howard Emerging challenges in AI and the need for AI ethics education AI and Ethics, 2021; 1: 61–65.
37. Almutairi, M. A., & Almutairi, A. M. The impact of artificial intelligence in pharmacy practice: a systematic review. Pharmacy and Pharmacology International Journal, 2019; 7(3): 128-135.

38. Junaid Bajwa, A Usman Munir, B Aditya NoriC and Bryan Williams-Artificial intelligence in healthcaretransforming the practice of medicine. 2021-0095(e188- e194).
39. Muhammad Ahmer Raza1,2; Shireen Aziz3,4;Misbah Noreen2,5; Amna Saeed6,7; Irfan Anjum8,9; MudassarAhmed2,5; Shahid Masood Raza, 2,4,10 2022; 13(2): 13. INNOVATIONS in pharmacy **DOI:** https://doi.org/10.24926/iip.v13i2.4839
40. Sri Harsha Chalasani a, Jehath Syed a, Madhan Ramesh a, Vikram Patil b, T.M. Pramod Kumar c Artificial intelligence in the field of pharmacy practice: A literature review, Exploratory Research in Clinical and Social Pharmacy, 2023; 12: 100346.
41. Subrat Kumar Bhattamisra 1, Priyanka Banerjee 2, Pratibha Gupta 2, Jayashree Mayuren 3, Susmita Patra 2and Mayuren Candasamy 4 Artificial Intelligence in Pharmaceutical and Healthcare Research Big Data Cogn. Comput, 2023; 7: 10. 10. https://doi.org/10.3390/bdcc7010010
42. Osama Khan a, Mohd Parvez b, Pratibha Kumari c, Samia Parvez d, Shadab Ahmad The future of pharmacy: How AI is revolutionizing the industry, Intelligent Pharmacy, 2023; 1: 32–40.
43. Flynn AllenUsing, artificial intelligence in health-system pharmacy practice: finding new patterns that matter Pharm.D., Ph.D Am J Health Syst Pharm., 2019; 76(9): 622-627, 10.1093/ajhp/zxz018.
44. Reed T. Sutton 1, David Pincock2, Daniel C. Baumgart1, Daniel C. Sadowski1, Richard N. Fedorak1 and Karen I. Kroeker1 An overview of clinical decision support systems: benefits, risks, and strategies for success npj Digital Medicine, 2020; 17.
45. Chaudhry, K. K., & Malhi, R. S. Artificial intelligence: the future of pharmacy. Journal of Global Pharma Technology, 2020; 12(11): 1-7.
46. OM. G. K. Jakir Hussain, Dr. T. CH. Anil Kumar, Dr. Licy Varghese, Dr. Pratheep K, Dr. S. Manochandar, Dr. R. Swaranalatha, Dr. Ch. Sandeep, Dr. Yogesh Arun Pund, Dr. Swati S Kale, Dr. Siddappaji M R Innovative Research: Uniting Multidisciplinary Insights, 1. March 2024 Doi: 10.25215/9358099984.23.
47. Terrence C. Lee1,2, Neil U. Shah1,2, Alyssa Haack1,2, Sally L. Baxter Clinical Implementation of Predictive Models Embedded within Electronic Health Record Systems: A Systematic Review Informatics(MDPI). Author manuscript; available in PMC 2020 December 02.
48. Artificial Intelligence Applications in education and Pharmacy Practice [Internet]2023. https://www.pharmacytimes.com/view/artificial-intelligence-applications-in-education-and-pharmacypracticeAvailable from. [Accessed on 15th June 2023] Artificial Intelligence

Applications in Education and Pharmacy Practice

49. Christopher L Robinson1, *, Ryan S D'Souza 2, *, Cyrus Yazdi1, Efemena M Diejomaoh3, Michael ESchatman 4,5, *, Trent Emerick 6, *, Vwaire Orhurhu7, Reviewing the Potential Role of Artificial Intelligence in Delivering Personalized and Interactive Pain Medicine Education for Chronic Pain Patients. Journal of Pain Research, 2024; 17. https://doi.org/10.2147/JPR.S439452 DovePress.