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A REVIEW ON ROLE OF ARTIFICIAL INTELLIGENCE IN PHARMACEUTICAL INDUSTRY

Mansi Jain, YashasviPardeshi, Dhara Patel, Dhananjay Meshram

Pioneer Pharmacy College, Nr.Ajwa Crossing, Sayajipura, Vadodara-390019, Gujarat, India

Email ID: patel.dhara.j@gmail.com

ABSTRACT

Artificial intelligence (AI) has emerged as a powerful tool that bringsup human intelligence and knowledge recombined with machine capabilities and provides solutions to complex challenges. AI technology has introduced transformation in the drug discovery, formulation, and testing of pharmaceutical dosage forms. By utilizing AI algorithms analysis of extensive data, including researches can be done.This enables a more efficient and targeted approach to drug discovery which increases success of drug approvals.AI contributes to reducing costs by optimizing research and development processes. Personalized medicine approaches can be facilitated through AI that analyze patient data, leading to more effective treatment outcomes and improved patient adherence. This review article explores the wide range applications of AI in drug discovery, drug delivery dosage form designs, process optimization, testing pharmacokinetics and pharmacodynamics studies. This article provides an overview of various AI based approaches utilized in pharmaceutical technology, highlighting their benefits and drawbacks. However, the continued investment in and exploration of AI in the pharmaceutical industry offer exciting prospects.

Keywords:

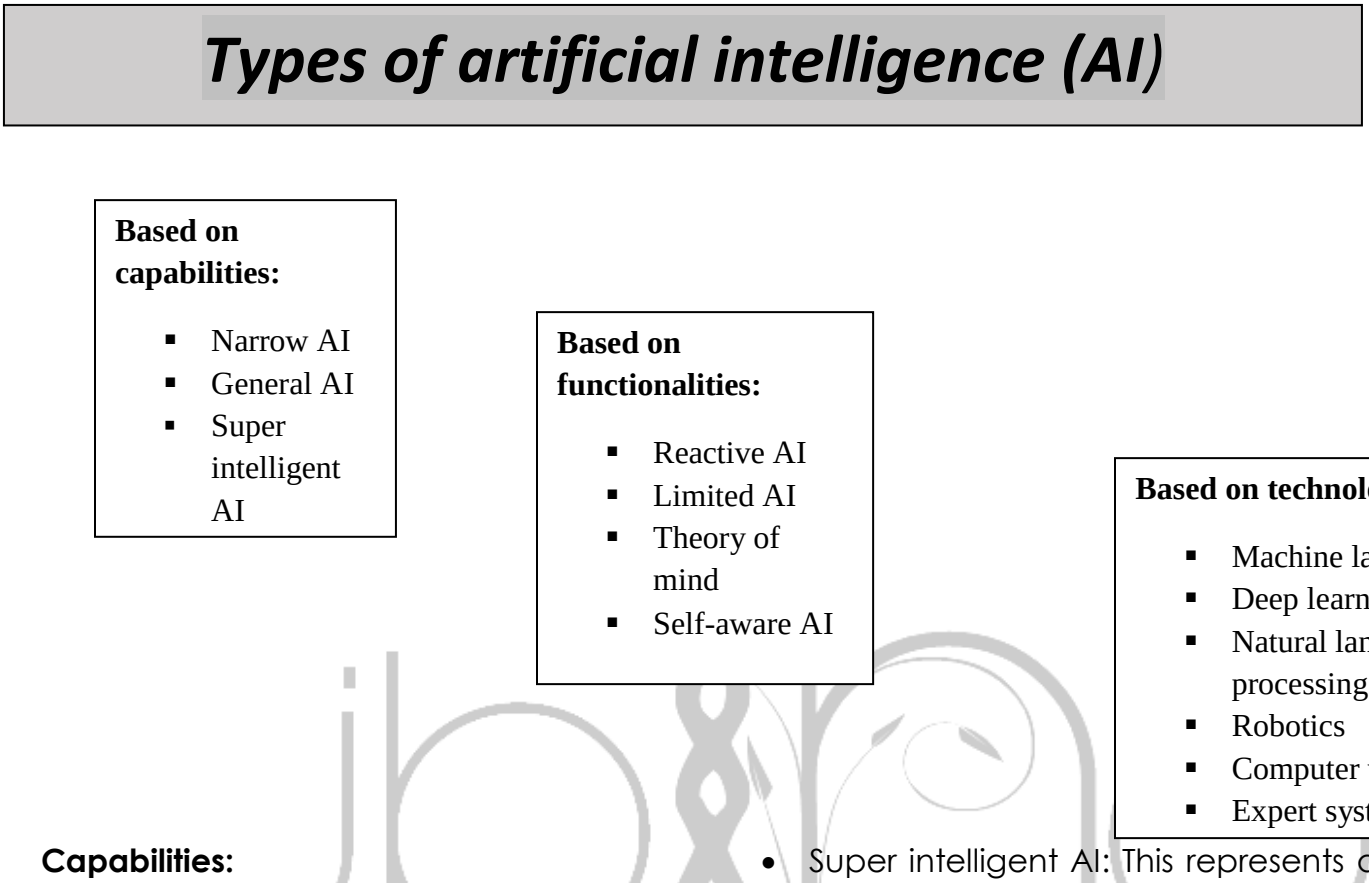
Artificial intelligence, AI algorithm analysis, drug discovery, patient data, process optimization, personalized medicine

Introduction:

Artificial Intelligence (AI) a concept of science fiction plays a central role in the contemporary technology scenery. It is an interconnected field that tackles algorithms and high-speed computations, enabling machines to learn from interactions with their surroundings. This allows for problem-solving and enhanced task performance over time[1]. The core of AI lies in simulation of human intelligence, allowing machines to exhibit skills such as reasoning, learning, problem-solving, perception, and understanding language.The father of AI is John McCarthy, a computer scientist who coined the term "artificial intelligence" in 1955. McCarthy is also credited with developing the first AI programming language, Lisp.The impact of AI in the current era is immense. At inception of a new era the integration of AI with other technological innovation is leading to a transformative shift across numerous societal sectors. AI is bringing revolution in field of health care and practice of pharmacy. AI is changing the way in which pharmacists deal with medication management, workflow stream and improving patient outcomes. The AI has to influence the future of the pharmaceutical industry as its potential applications, benefits, challenges and the capacity for its potential role in pharmacy.In pharmacy practice, AI technology has a wide range of applications, enabling pharmacists to make decisions based on wide-current data[2]. Medication management is one of the key areas in which AI can make an impact.AI controlled decisions support the pharmacists to choose the right drug, dosage, identify possible drug interactions and adverse effects. Also, AI driven resources can improve the potential of medical judgment, its applications, benefits, challenges and the capacity of medication errors.AI algorithms are bringing transformation in drug discovery process by analyzing large data and bringing out more accuracy, identifying potential drug nominee. Due to the acceleration of drug development, new treatments for a variety of diseases may be developed such as Cancer, acquired immunodeficiency syndrome (AIDs), cardiovascular disease (CVDs), strokes etc.AI focuses on personalized treatment by helping to develop medicinal plans based on an individual patient's genetic makeup, lifestyle and history. This personalized approach reduces adverse drug reactions (ADRs) while improving treatment outcomes.AI simplifies pharmacy workflow, reduces administrative burden, and eliminates focus on patient care[3]. Robotic dispensing is a method of AI that is enhancing the effectiveness of pharmaceutical procedures. Automated dispensing systems can accurately package and label medications, improving efficiency and reducing errors. Currently in India many large pharmaceutical companies have adopted AI automated dispensing systems with a high success rate such as Pfizer, Rxprism, Tricog Health etc. AI can also assist pharmacies with inventory management. AI regulated algorithms predict drug demand and optimize inventory management, maintaining adequate stock levels and reducing waste.Pharmacists are highly concerned

about patient safety and AI may help in this area. The integration of AI technologies in pharmacy practice can help detect and prevent medication errors, such as incorrect dosages or potential drug interactions, thereby minimizing ADRs and hospital admissions.AI monitors patient data and identifies early signs of adverse effects (AEs), allowing timely intervention and preventing serious consequences. AI-powered systems may monitor a patient's compliance with their drug regimen and provide reminders and individualized notifications to promote compliance, which can improve medication compliance and treatment outcomes.Despite its potential, the implementation of AI in pharmacies faces several challenges. Some pharmacies may find the initial expense required for AI integration to be challenging, particularly smaller organizations with limited finances and resources.Comprehensive education and training is necessary to create trust in AI driven operations because some pharmacists may be reluctant to adopt AI. Looking ahead it promises a bright future for the pharmacy industry.As AI technology develops, its capabilities will continue to expand, bringing more complex and precise solutions to the practice of pharmacy. Collaboration between pharmacists, AI developers, and health care providers will drive innovation and refine AI tools to meet specific pharmacy needs.WHO recognizes that AI holds great promise for the advancement of human health and for attainment of universal health coverage; however, AI also presents risks and ethical challenges that must be addressed if societies, health systems and individuals are to fully reap its benefits.The implementation of AI is poised to bring about a significant transformation in the way the pharmaceutical industry handles supply chain operations.AI tools also make patient care more consistent by reducing deviations in the manufacture and delivery of therapeutics. By automating tedious and time-consuming tasks like document creation and record keeping, AI stands to boost the productivity of researchers and medical association, so they can better serve clinicians and patients.The role of AI in pharmaceutical practice has brought transformation. From improving patient safety and treatment outcomes to streamlining workflows and delivering personalized care, AI is reshaping the way pharmacists deliver their services.However, it is crucial to address the challenges, provide necessary training, and work together to harness AI's potential for the betterment of pharmacy practice and patient care[3,5]. AI is revolutionizing the field of pharmacy by changing the way pharmacists provide their services, from enhancing patient safety and treatment results to optimizing operations and providing individualized care.

2. Different types of AI[5-6]



Capabilities:

- Narrow AI (Weak AI): This type of AI is designed to perform a narrow task e.g., facial recognition, internet searches, or driving a car. Most current AI systems, including those that can play complex games like chess and Go, fall under this category. They operate under a limited pre-defined range or set of contexts.
- General AI (Strong AI): A type of AI endowed with broad human-like cognitive capabilities, enabling it to tackle new and unfamiliar tasks autonomously. Such a robust AI framework possesses the capacity to discern, assimilate, and utilize its intelligence to resolve any challenge without needing human guidance.
- Super intelligent AI: This represents a future form of AI where machines could surpass human intelligence across all fields, including creativity, general wisdom, and problem-solving. Super intelligence is speculative and not yet realized.

2. Based on Functionalities:

- Reactive Machines: These AI systems do not store memories or past experiences for future actions. They analyze and respond to different situations.Eg: IBM's Deep Blue, which beat Garry Kasparov at chess in 1997, are based on reactive AI, analyzing the board's current state to make optimal moves.
- Limited Memory: These AI systems can make informed and improved decisions by studying the past data they have

collected. Most present-day AI applications, from chat bots and virtual assistants to self-driving cars, fall into this category.

- Theory of Mind: This is a more advanced type of AI that researchers are still working on. It would entail understanding and remembering emotions, beliefs, needs, and depending on those, making decisions. This type requires the machine to understand humans truly.
- Self-aware AI: This represents the future of AI, where machines will have their own consciousness, sentience, and self-awareness. This type of AI is still theoretical and would be capable of understanding and possessing emotions, which could lead them to form beliefs and desires.

3. Based on technology:

- Machine Learning (ML): AI systems capable of self-improvement through experience, without direct programming. They concentrate on creating software that can independently learn by accessing and utilizing data.
- Deep Learning: A subset of ML involving many layers of neural networks. It is used for learning from large amounts of data and is the technology behind voice control in consumer devices, image recognition, and many other applications.
- Natural Language Processing (NLP): This AI technology enables machines to understand and interpret human language. It's used in chatbots, translation services, and sentiment analysis applications.
- Robotics: This field involves designing, constructing, operating, and using robots and computer systems for controlling them, sensory feedback, and information processing.
- Computer Vision: This technology allows machines to interpret the world visually, and it's used in various applications such as medical image analysis, surveillance, and manufacturing.
- Expert Systems: These AI systems answer questions and solve problems in a specific domain of expertise using rule-based systems.

3. Background[6-8]:

Core Concepts of AI:

Artificial Intelligence encloses various concepts and terms. This section aims to clarify the essential concepts supporting AI, highlighting how these ideas converge and grow intelligent systems that revolutionize industries and daily life.

1. Machine Learning:

Machine Learning is a subset of AI that equips systems with the ability to learn from data, enhancing their performance and enabling decision making without specific programming. It employs statistical methods to empower machines to improve through experience. AI and ML share a reciprocal relationship machine learning supplies the algorithms to which AI provides the framework.

2. Real-World Machine Learning:

Predictive Analytics: ML algorithms forecast stock market trends and pinpoint investment opportunities in the finance sector.

Recommendation Systems: ML powers Amazon and Netflix's systems to suggest products or content by analyzing user preferences and behavior.

Fraud Detection: ML scrutinizes vast datasets to identify fraudulent patterns and activities.

3. Deep Learning

Deep Learning is a ML subset that uses multi-layered artificial neural networks to analyze data at various levels. It stands out in AI for its superior accuracy and efficiency, particularly with extensive datasets. Image and Speech Recognition excels in identifying speech and image patterns, enabling technologies like voice assistants and facial recognition.

4. Natural Language Processing:

It enhances machines' capacity to process and respond to natural language inputs. Natural Language Processing facilitates interactions between computers and human languages, enabling machines to comprehend, interpret, and produce human language meaningfully.

NLP Industry Applications:

Customer Service: Chatbots and virtual assistants employ NLP to comprehend and address customer inquiries.

- ✓ Healthcare: NLP transforms free-text medical notes into structured, analyzable data, aiding in predictive analytics and decision-making.
- ✓ Legal: NLP analyses vast legal document volumes to extract vital information and insights.

5. Autonomous Systems:

Crucial for autonomous vehicles, Deep Learning facilitates real-time complex environment navigation.

4. BIOSTATISTICS OF AI[3, 5-7]

The pharmaceutical industry is rapidly evolving and the number of AI application integrations is increasing day by day, reshaping every facet of pharmaceutical processes from drug discovery to supply chain management.AI applications can potentially create between $350 billion and $410 billion in annual value for pharmaceutical companies by 2025. The pharmaceutical market is projected to grow at a compound annual growth rate (CAGR) of 42.68%, approximately equal to a $15 billion growth between 2024 to 2029

Countries driving adoption of artificial intelligence in pharmaceutical industry

The US is the leading country in AI adoption within the pharmaceutical industry, boasting the highest number of AI-related patents, jobs, and deals. Meanwhile, the UK, China, South Korea and Australia also maintain significant positions in AI adoption within the pharmaceutical industry.

Should Artificial Intelligence Be Used in Healthcare?

AI has doubtless potential to improve healthcare systems. Automating tedious tasks can free up clinician schedules to allow for more patient interfacing. Improving data accessibility assists healthcare professionals in taking the right steps to prevent illness. Real-time data can better and more rapidly inform diagnoses. AI is being implemented to reduce administrative errors and save vital resources. Small and medium enterprises (SMEs) are increasingly involved in AI development, making the technology more applicable and better-informed. AI is increasingly applied to healthcare, and limits and challenges continue to be confronted and overcome. AI still requires some human surveillance, may exclude social variables, experiences gaps in population information and is susceptible

to increasingly-calculated cyberattacks. Despite some of the challenges and limits AI faces, this innovative technology promises extraordinary benefits to the medical sector. Whether a patient or physician, lives everywhere are improving thanks to AI.

5. CURRENT SCENARIO IN PHARMACEUTICAL INDUSTRY[9-11]

In today's data-driven age, companies never fail to grab a single market opportunity to make the business processes better, smarter and more efficient. Data science acts as the fuel behind this rising tide. But Artificial Intelligence and Machine Learning, companies can now touch the peak of efficiency in data analysis that leaves a great impact on their entire businesses.The way industries are adopting AI and machine learning, it will eventually drive remarkable growth in the coming years. Research says the AI market will reach $89.8 Billion in Annual Worldwide Revenue by 2025.In a broad sense, Artificial Intelligence is involved with computer systems performing tasks that usually need human intelligence. It can be amazingly useful in managing data and presenting results that promote better decision making and help saving human effort, cost and time. However, many companies using traditional methods to run their healthcare business are yet to adopt this technology. But what they are not understanding is without using Artificial Intelligence, a pharma industry can be affected in various ways:Medical information collection and processing can be slowed down.Unavailability of data and medical records.Costly and time-consuming drug discovery and research and development (R&D) process.Therefore, application AI with machine learning is highly necessary for making all the healthcare-related processes seamless, cost-effective, efficient and hassle-free.

AI usage has grown rapidly in recent years. According to the latest surveys, 80% of pharmaceutical and life sciences professionals use AI for drug discovery. According to another study, AI technology reduces the time it takes pharmaceutical companies to discover new drugs from 5-6 years to just one year.

Applications of AI in Pharma

1. Quality Control and Quality Assurance(QA &QC):

2. Pharmaceutical Product Management:

- arket Positioning
- arket Analysis and Prediction
- roduct Costing

3. Pharmaceutical product development

- id in deciding excipients
- onitoring and modifying process
- nsuring in-process specification

4. Clinical Trial Design and monitoring:

- ubject enrollment section
- arket Analysis and Prediction
- roduct Costing

5. Drug Discovery:

- rug design (drug protein interaction, targeted protein structure)
- rug-screening (toxicity prediction, bioactivity prediction, physicochemical properties prediction).

6. Pharmaceutical Manufacturing

- utomated Manufacturing
- ersonalized Manufacturing
- orrelating manufacturing errors to set parameters.

6. Pharmaceutical Companies using AI

While pharma companies are making big bets on AI, the actual impacts and outcomes of many initiatives remain largely behind the scenes. Still, there are some examples that provide a glimpse into how AI may be shaping the future of drug development and healthcare. Below, discover how 11 Big Pharma companies are using AI to transform the landscape of drug discovery, clinical trials and manufacturing.Sanofi partnered with Ailey Labs to develop an AI platform called "Plai" in 2018, with the goal of using AI for drug discovery, clinical trials and manufacturing. Lai aggregates Sanofi's internal data to support decision making across the drug development process. Sanofi has also partnered with Hillo to adapt its AI technology for connected insulin pens, demonstrating the company's interest in using AI for both drug development and connected healthcare products.Pfizer has used IBM's supercomputing and AI since 2020 to develop new drugs like PAXLOVID, an oral COVID-19 treatment approved in 2022. They claim this reduced computational time by 80-90%, stating that the technology helped the team design the drug in four months. The Big Pharma has also inked a deal with CytoReason, which has created an AI model of the immune system.Novartis is employing AI to improve drug discovery and boost efficiency. The firm has more than 150 ongoing projects applying AI across the business. Novartis partnered with Microsoft and NVIDIA, and aims to scale AI over a decade to improve access, costs, and health outcomes, though outcomes so far are unclear.Janssen is exploring AI for drug discovery, clinical trials, diagnosing diseases and manufacturing, as sister site Drug Discovery & Development noted. Its Trials360.ai service optimizes trial design, improving care and outcomes. With more than 100 AI projects, Janssen is adopting a scalable approach to test and deploy AI.

AstraZeneca partnered with Oncoshot in 2021 to match patients to trials using AI and BenevolentAI to identify targets, though the timescale and outcomes of these partnerships are unknown. The latter partnership has proven successful with AstraZeneca selecting five targets to enter its portfolio. Two are in chronic kidney disease (CKD) and three in idiopathic pulmonary fibrosis (IPF). Since then, the companies have expanded the partnership to systemic lupus erythematosus and heart failure.Bristol Myers Squibb has partnered with Exscientia to use AI for small molecule drug discovery. The collaboration will use Exscientia's AI

platforms to accelerate the discovery of small molecule drug candidates across multiple disease areas, including oncology and immunology. By combining Exscientia's AI expertise with BMS's experience in drug development, the partners aim to speed up the early stages of the drug pipeline.Bayer has also partnered with Exscientia to explore AI for small molecule drug discovery. Exscientia will collaborate with Bayer on three initial projects focused on cardiovascular disease and oncology targets. Under the agreement, Exscientia may receive up to €240 million in payments, including upfront research funding, clinical milestones, and near-term milestones. The partnership aims to combine Exscientia's AI platform with Bayer's expertise in drug development to speed up the discovery of new small molecule drug candidates for some of Bayer's key disease areas of focus.

Merck partnered with BenchSci, Atomwise, C4 Therapeutics and ACMED on various AI drug discovery and development initiatives.GSK has partnered with Cloud Pharmaceuticals and Insilico Medicine to utilize their AI platforms for target identification, drug design, and lead generation. GSK also has an Advantage AI program to explore AI partnerships.Roche partnered with Recursion Pharmaceuticals to use their AI platforms for drug discovery and development. After announcing more than 25 AI partnerships, Roche established an AI hub.Lilly, a $420 billion Big Pharma, recently told Insider it aims to grow its 'digital worker-equivalent workforce' to 2.4 million hours, or 274 years of human work, by year-end through more than 100 AI projects. CEO David Ricks noted that he sees AI augmenting human productivity, automating regulatory processes, and enabling new drug discovery constructs chemists wouldn't visualize alone. Ricks expects AI to 'massively change the productivity of the workplace,' freeing people for more valuable work.

Use of AI in Pharma[12-14]:

Drug discovery and design

From designing new molecules to identifying novel biological targets, AI is playing a role in drug target identification and validation; target-based, phenotypic, as well as multi-target drug discoveries; drug repurposing; and biomarker identification. The key benefit for pharma companies is the potential for AI, especially when implemented during drug trials, to reduce the time it takes a drug to get approval and reach the market. This can result it great cost savings, which could mean lower cost drugs for patients, as well as more treatment choices.

For example, pharma researchers can identify and validate novel cancer drug targets using data such as longitudinal electronic medical records (EMR records), next generation sequencing, and other omic data are used to create representative models of individual patients.

Drug repurposing

For budget-pressed pharma companies, repurposing drugs promises to be one of the most immediate areas that AI-based technologies can deliver great value. Repurposing previously known drugs or late-stage drug candidates towards new therapeutic areas is a desired strategy for many biopharmaceutical companies as it presents less risk of unexpected toxicity

or side effects in human trials, and, likely, less R&D spend.

Drug adherence and dosage

Ensuring compliance to a drug study protocol by voluntary participants in clinical studies is a huge problem for pharma companies. If patients in a drug study don't follow the trial rules, they must either be removed from the study or risk corrupting the drug study results. One of the important factors of a successful drug trial is ensuring that participants take the required dosage of the studied drug at the prescribed times. That's why having a way to ensure drug adherence is so important. Both through remote monitoring and algorithms for evaluating test results, AI can sort the good apples from the bad.

Rare diseases and personalized medicine

Combing information from body scans, patient biology and analytics, AI is being used in various ways to detect diseases such as cancer, and even predict health issues people might face based on their genetics. One example is the IBM Watson for Oncology, which uses each patient's medical information and history to recommend a personalized treatment plan.

AI is also being used to develop personalized drug treatments based on an individual's test results, reactions to past drugs and historical patient data for drug reactions.

Limits of AI in Medicine[14,15]:

Needs human surveillance

Although AI has come a long way in the medical world, human surveillance is still essential. For example, surgery robots operate logically, as opposed to empathetically. Health practitioners may notice vital behavioural observations that can help diagnose or prevent medical complications.

"AI has been around for a few decades and continues to mature. As this area advances, there is more interaction between healthcare professionals and tech experts," Yang explains. AI requires human input and review to be leveraged effectively.

As AI develops, the tech and medical fields are increasingly communicating to improve the technology. Yang adds, "Years of education are required for medical professionals to operate in their fields. Essential information gathered from Subject Matter Experts (SMEs) enriches the data available and improves explainable AI (XAI) to provide healthcare workers with trusted and valuable insights."

May overlook social variables

Patient needs often extend beyond immediate physical conditions. Social, economic and historical factors can play into appropriate recommendations for particular patients. For instance, an AI system may be able to allocate a patient to a particular care centre based on a specific diagnosis. However, this system may not account for patient economic restrictions or other personalized preferences.

Privacy also becomes an issue when incorporating an AI system. Brands like Amazon have free reign when it comes to collecting and leveraging data. Hospitals, on the other hand, may face some setbacks when attempting to channel data from Apple mobile devices, for instance. These regulatory and social

restrictions may limit AI's ability to facilitate medical practices.

May lead to unemployment

Although AI may help cut costs and reduce clinician pressure, it may also render some jobs redundant. This variable may result in displaced professionals who invested time and money in healthcare education, presenting equity challenges.A 2018 World Economic Forum report projected AI would create a net sum of 58 million jobs by 2022. However, this same study finds 75 million jobs will be displaced or destroyed by AI by the same year. The major reason for this elimination of job opportunities is, as AI is more integrated across different sectors, roles that entail repetitive tasks will be redundant.Though AI promises to improve several aspects of healthcare and medicine, it's vital to consider the social ramifications of integrating this technology.

Inaccuracies are still possible

Medical AI depends heavily on diagnosis data available from millions of catalogued cases. In cases where little data exists on particular illnesses, demographics, or environmental factors, a misdiagnosis is entirely possible. This factor becomes especially important when prescribing particular medicine.Remarking on this data gap, Yang says, "No matter the system, there is always some portion of missing data. In the case with prescriptions, some information regarding certain populations and reactions to treatments may be absent. This occurrence can lead to issues with diagnosing and treating patients belonging to certain demographics."AI is constantly evolving and improving to account for data gaps. However, it's important to note that specific populations may still be excluded from existing domain knowledge.

Susceptible to security risks

As AI is generally dependent on data networks, AI systems are susceptible to security risks. The onset of Offensive AI, improved cyber security will be required to ensure the technology is sustainable. According to Forrester Consulting, 88% of decision-makers in the security industry are convinced offensive AI is an emerging threat.

Conclusion:

AI is transforming pharmaceutical technologies by enabling targeted, personalized and adaptive approaches. AI's capabilities in data analysis, recognition and optimization have assisted pharmaceutical researchers and healthcare professionals to enhance drug efficacy, minimize side effects and improved patient compliance. AI based methods have revolutionized the field of pharmacokinetics and pharmacodynamics. It offers several advantages over traditional experimental methods. AI-based models can predict provide a more efficient, cost-effective and data-driven approach regarding pharmacokinetic parameters, simulate drug distribution and clearance in the body, and optimize drug dosage and administration routes. AI based models can simplify development and optimize the parameters, reducing need of animal studies and human clinical trials there by increasing productivity and reducing resources. AI regulated computational pharmaceutics enablesupgrades drug formulations, personalized therapies, dose

administration and risk reduction, ultimately leading to improved drug manufacturing processes and enhanced patient outcomes. Overall, the integration of AI technologies holds great promise for accelerating drug development.AI can also make major contributions to the further incorporation of the developed drug in its correct dosage form as well as its optimization, cost cutting, in addition to aiding quick decision making, leading to faster manufacturing of better quality products along with assurance of batch-to-batch consistency through comprehensive market analysis and prediction. Yet due to lack of skilled personnel to operate AI based platforms, limited budget for small organizations, apprehension of replacing humans leading to job loss, doubtfulness about the data generated by AI and the black box phenomenon there are no drugs currently in the market developed with AI based approaches and specific challenges remain with regards to the implementation of this technology, it is likely that AI will become an invaluable tool in the pharmaceutical industry in the near future.

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