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THE PARADIGM OF ARTIFICIAL INTELLIGENCE (AI) IN DRUG DISCOVERY AND DRUG DEVELOPMENT - A REVIEW

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Abstract:

Artificial intelligence has decreased the workload of humans and improved the human standard of living. Artificial intelligence widening over the world not only in drug discovery and development of the drug but also in other aspects too. This article is mainly related to a paradigm shift of artificial intelligence (ai) in drug discovery and development to make them more operative and precise. Artificial intelligence has been increasing more in pharmaceutical industries. Conventional drug discovery is a spectacularly time-consuming and overpriced process. At the same time ai tools are modifying every stage of the drug discovery and development process, ai tools alter the speed and economics of the pharmaceutical industry. Artificial intelligence has been altering dramatically in many strands of pharmaceuticals. In this review article, we focus on the use of ai in different regions of pharmaceutical industries, along with drug discovery and development, enhancing pharmaceutical productivity and clinical trials.

Keywords: *Paradigm, Artificial Intelligence, Machine Learning, Deep Learning*

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INTRODUCTION:

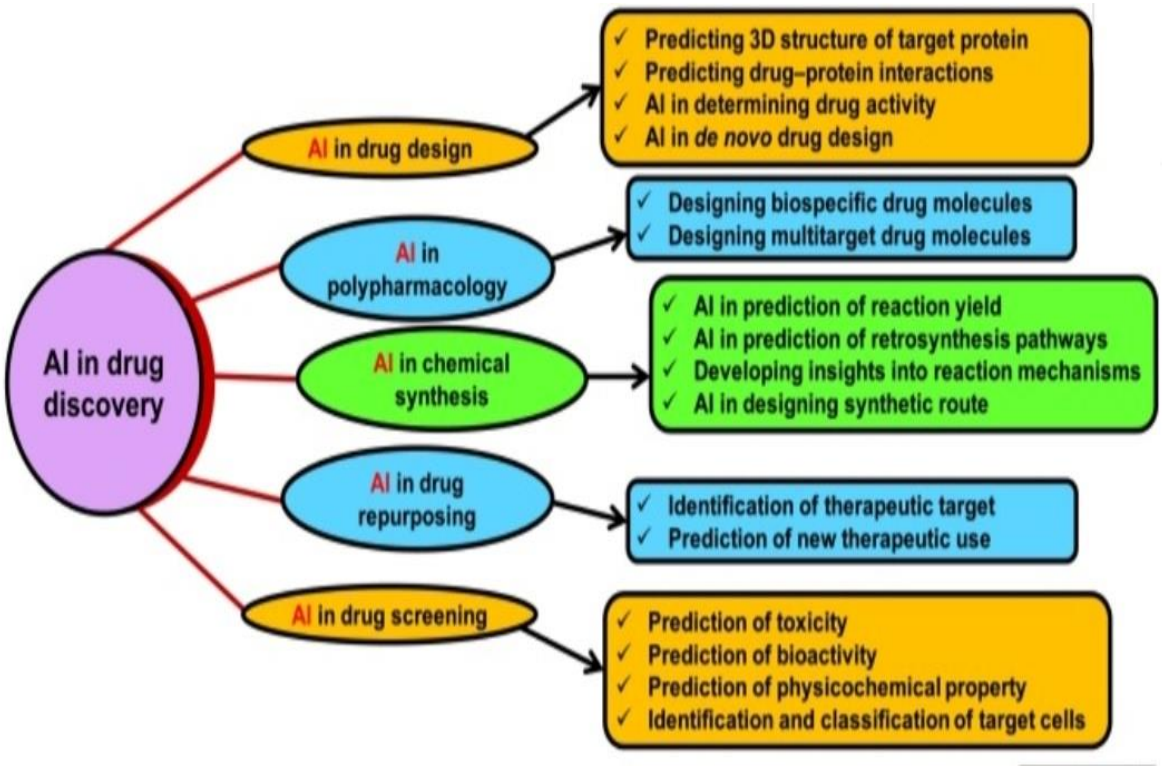
The use of **Artificial Intelligence (AI)** has been increasing in various sectors of society, particularly the pharmaceutical industry. In this review, we highlight the use of AI in diverse sectors of the pharmaceutical industry, including drug discovery and development – a Paradigm shift; such use reduces the human workload as well as achieving targets by relying more on machine learning through observation of their own in a short period of time [1]. Over the past few years, there has been a drastic increase in data digitalization in the pharmaceutical sector. However, this digitalization comes with the challenge of acquiring, scrutinizing, and applying that knowledge to solve complex clinical problems [1]. This motivates the use of AI because it can handle large volumes of data with enhanced automation. For many decades, the manufacturing of drug products has been controlled by a regulatory framework that safeguards the quality of final products by testing raw materials, in-process materials, end-product characteristics, batch-based operations, and fixed process conditions. The drug and biopharmaceutical industries have been limited sources of inventive and novel technologies or machinery, and have led the development of novel principles or interpretations in general chemical and mechanical engineering [2]. The pharmaceutical industry is in critical need of mechanical innovation, easing the creation of medications for human use. The use of artificial intelligence (AI) is increasing and is likely to change how clinical examination and training are carried out. Doctors can participate in the development of this technology for use in the medical and pharmaceutical industries; this will ensure that the potential of AI to significantly improve medical care is fulfilled. [2]

AI is currently used in the pharmaceutical industry in four main ways. The first is in the assessment of the severity of the disease and the prediction of whether treatment will be successful for an individual patient, even prior to its administration [1]. Secondly, it is used to prevent or solve complications during treatment. Its third main use is as an assistive technology during treatment procedures or operations on patients. Lastly, this short review discussed how to determine the reasons behind the use of particular instruments or chemicals during treatment and to develop or extrapolate new uses for instruments or chemicals to improve safety and efficacy.[3]

Drug discovery:

The discovery of a novel drug molecule requires its subsequent incorporation in a suitable dosage form with desired delivery characteristics. In this area, AI can replace the older trial-and-error approach. Various computational tools can resolve problems encountered in the formulation design area, such as stability issues, dissolution, porosity, and so on, with the help of Quantitative Structure-Property Relationship (QSPR).[3,4] AI offers significant technological advances that may represent a paradigm shift in drug discovery and, ultimately, clinical development. We believe passages that now feel like a sea change will rapidly become table stakes in discovery speed, novelty, and commercial potential. [6]

FIGURE:1



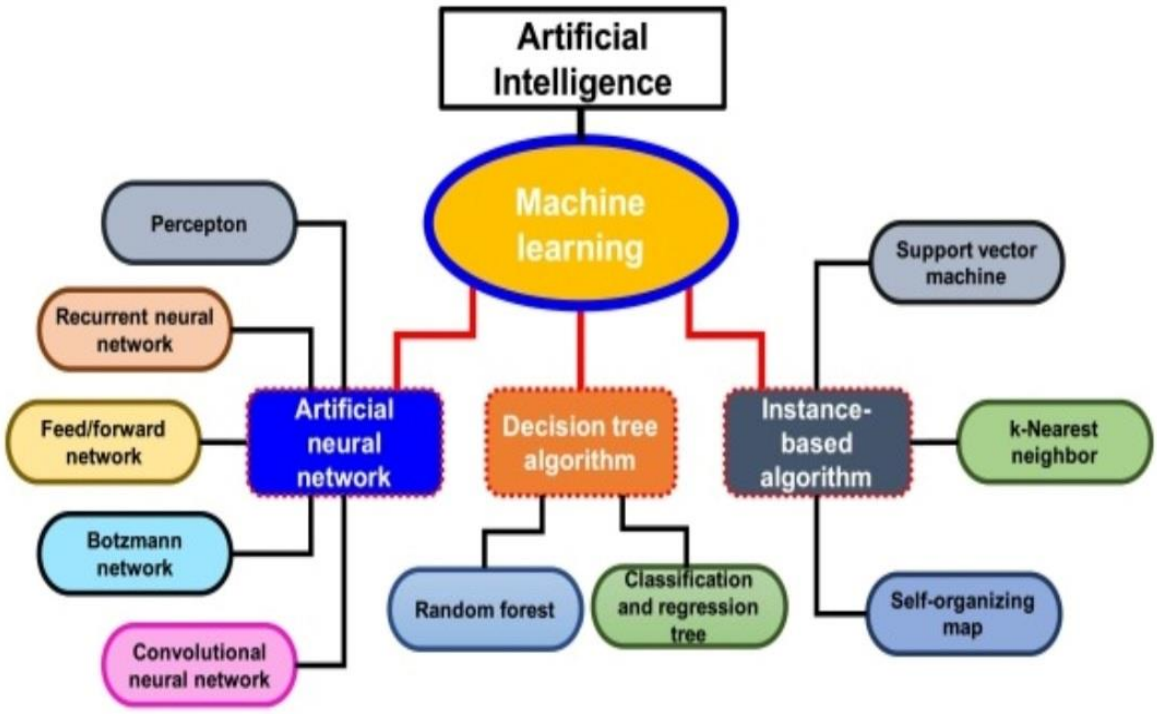
TECHNIQUES INVOLVED IN AI DRUG DISCOVERY:

The vast chemical space, comprising more than 1060 molecules, fosters the development of a large number of drug molecules. However, the lack of advanced technologies limits the drug development process, making it a time-consuming and expensive task, which can be addressed by using AI. AI can recognize hit and lead compounds, and provide a quicker validation of the drug target and optimization of the drug structure design. Different applications of AI in drug discovery are depicted.[2]

Two common types of AI techniques, namely, supervised and unsupervised learning, are used in the field of drug discovery. A supervised learning technique uses input-labeled data to train models that are capable of classifying or predicting outcomes of new data [3]. By contrast, an unsupervised learning technique deals with unlabeled data and aims to develop models that are capable of identifying recurring patterns and clustering of the input data in a manner without prior knowledge. Supervised learning techniques can be further classified into classification and regression algorithms, and unsupervised learning techniques include clustering and dimensionality reduction algorithms. techniques in drug discovery are listed in Table and briefly discussed below.[3]

Algorithms, such as Nearest- neighbor classifiers, RF, extreme learning machines, SVMs, and deep neural networks (DNNs), are used for VS based on synthesis feasibility and can also predict in vivo activity and toxicity. Several biopharmaceutical companies, such as Bayer, Roche, and Pfizer, have teamed up with IT companies to develop a platform for the discovery of therapies in areas such as immuno-oncology and cardiovascular diseases. [4]

FIGURE:2



AI: NETWORKS AND TOOLS:

AI involves several method domains, such as reasoning, knowledge representation, solution search, and, among them, a fundamental paradigm of Machine Learning (ML). ML uses algorithms that can recognize patterns within a set of data that has been further classified. A subfield of ML is Deep Learning (DL), which engages Artificial Neural Networks (ANNs).[5] These comprise a set of interconnected sophisticated computing elements involving 'perceptions' analogous to human biological neurons, mimicking the transmission of electrical impulses in the human brain. ANNs constitute a set of nodes, each receiving a separate input, ultimately converting them to output, either singly or multi-linked using algorithms to solve problems. ANNs involve various types, including Multi-Layer Perceptron (MLP) networks, recurrent neural networks (RNNs), and convolutional neural networks (CNNs), which utilize either supervised or unsupervised training procedures. [3]

TABLE:1

CATEGORY	TASK	METHOD	REPRESENTATIVE APPLICATION
Supervised Learning	Regression analysis	**MLR** **DT** **LR**	DTI Adverse drug reactions Drug – Drug interactions
	Classification	**SVM** **CNN** **RNN** **GAN**	Compound classification Bioactivity prediction De Novo drug design Molecule discovery
Unsupervised Learning	Clustering	**K- means** **Hierarchical**	Drug candidate selection Molecular scaffold analysis
	Dimension reduction	**PCA** **t-SNE**	QSAR Chemical space mapping

MODELS FOR AI IN THE PHARMA INDUSTRY:

The MLP network has applications including pattern recognition, optimization aids, process identification, and controls, are usually trained by supervised training procedures operating in a single direction only, and can be used as universal pattern classifiers [8]. RNNs are networks with a closed-loop, having the capability to memorize and store information, such as Boltzmann constants and Hopfield networks. CNNs are a series of dynamic systems with local connections, characterized by their topology, and have use in image and video processing, biological system modeling, processing complex brain functions, pattern recognition, and sophisticated signal processing.[9]

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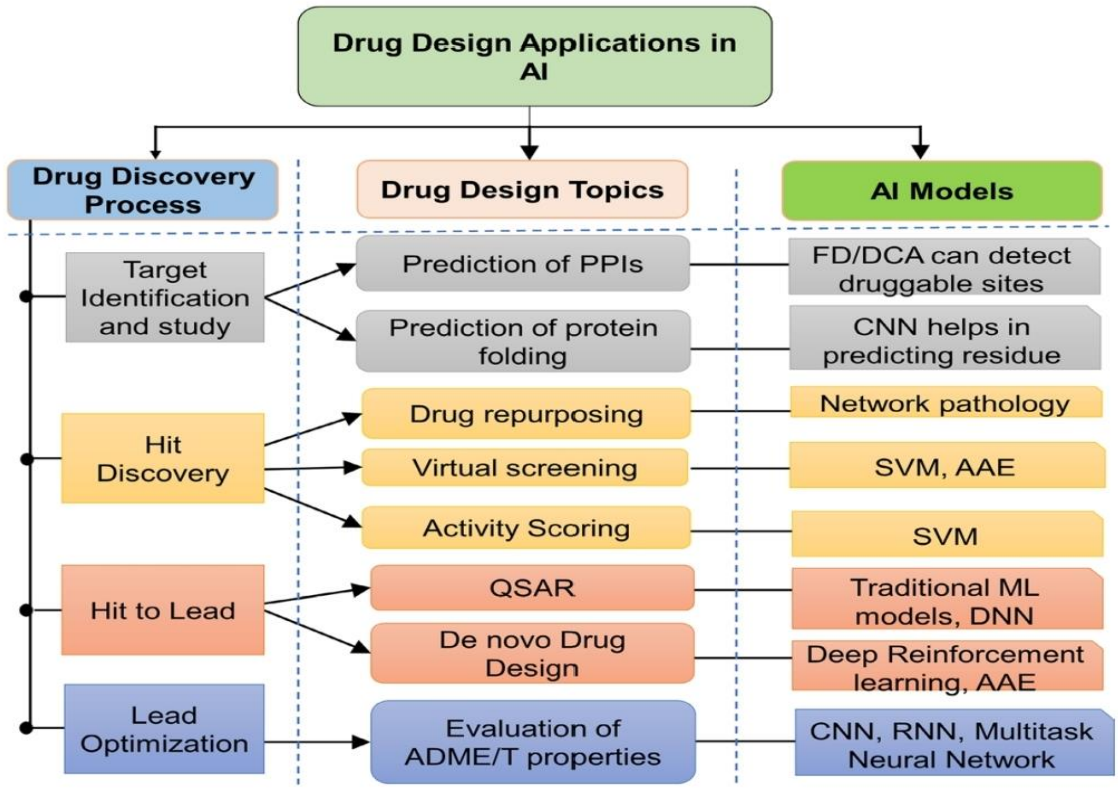
Table 2 : Examples of AI tools used in Drug Discovery:

TOOLS	DETAILS
Deep Chem	MLP model that uses a Python-based AI system to find a suitable candidate for drug discovery
Deep Tox	Software that predicts the toxicity of a total of 12000 drugs
Deep Neural Net QSAR	Python-based system driven by computational tools that aid the detection of the molecular activity of compounds
Organic	A molecular generation tool that helps to create molecules with desired properties
Potential Net	Uses NNs to predict the binding affinity of ligands
Hit Dexter	ML technique to predict molecules that might respond to biochemical assays
Delta Vina	A scoring function for rescoring drug-ligand binding affinity
Neural graph fingerprint	Helps to predict the properties of novel molecules
Alpha Fold	Predict 3D structures of proteins
Chemputer	Helps to report procedure for chemical synthesis in standardized format

AI IN DESIGNING DRUG MOLECULES:

While developing a drug molecule, it is essential to assign the correct target for successful treatment. Numerous proteins are involved in the development of the disease and, in some cases, they are overexpressed. Hence, for selective targeting of disease, it is vital to predict the structure of the target protein to design the drug molecule [7]. AI can assist in structure-based drug discovery by predicting the 3D protein structure because the design is in accordance with the chemical environment of the target protein site, thus helping to predict the effect of a compound on the target along with safety considerations before their synthesis or production.[8]

FIGURE:3



Predicting drug-protein interactions:
Drug–protein interactions have a vital role in the success of a therapy. The prediction of the interaction of a drug with a receptor or protein is essential to understanding its efficacy and effectiveness, allows the repurposing of drugs, and prevents polypharmacology. Various AI methods have been useful in the accurate prediction of ligand–protein interactions, ensuring better therapeutic efficacy [6]. The ability of AI to predict drug–target interactions was also used to assist in the repurposing of existing drugs and avoiding polypharmacology. Various AI methods have been useful in the accurate prediction of ligand–protein interactions, ensuring better therapeutic efficacy.[8]

De Novo drug design:
AI in de novo drug design Over the past few years, the de novo drug design approach has been widely used to design drug molecules [7]. The traditional method of de novo drug design is being replaced by evolving DL methods, the former having shortcomings of complicated synthesis routes and difficult prediction of the bioactivity of the novel molecule.[10]

ADVANTAGES OF AI IN PHARMACEUTICAL INDUSTRIES:

Artificial intelligence has a positive impact on the entire pharmaceutical industry. The industry is trying to follow:

Conducting Repetitive Task.
With AI, doing data entry, analyzing medical test reports, and performing other tasks that seem mundane and time-consuming, can be done repetitively in a faster and swifter way [5]. As a result, doctors and additional healthcare providers can have more time to focus on other urgent and complex jobs and interact with patients in a better way.[12]

Managing Data:
Undoubtedly, one of the most important parts of healthcare is collecting and analyzing data, such as test reports and past medical records. With Artificial Intelligence, data management in the healthcare sector has become a hassle-free process. Al the data

can be collected, stored, reformatted, and traced in assistance with digital automation in a fast and consistent way.[13]

Analyzing Healthcare Systems:
Artificial Intelligence analyzes the healthcare systems properly and helps healthcare providers make the best decisions to keep the system organized and make patient care better. The invoice generation process can be digital [8]. Also, some organizations sift through the medical records to highlight errors in treatments and inefficiency in the workflow. As a result, the entire healthcare system can avoid patient hospitalizations that are simply not needed.[11]

Leveraging the Advantages of Natural-language processing:
Being an important component of Artificial Intelligence, natural language processing is the capability of a computer program to comprehend human speech. In the healthcare industry, with natural language processing, a massive amount of electronic medical records can be analyzed. Additionally, the right steps to evaluate and handle patients with multiple diseases can be taken.[10]

Making the Medical Consultation Process Digital:
There are a few AI-based apps that are specially designed to give medical consultation based on the details of a patient's illness symptoms and past medical records. Users can add their symptoms to the app. Then the app can suggest recommended action after going through the user's medical history. These apps are minimizing the overall rate of misdiagnosis.[11]

Maximizing the Benefits of Digital Nurses:
Digital or virtual nurses follow up with the patients between doctor appointments. It is a great technological advancement of AI that can minimize unneeded hospital visits. Eventually, it reduces the load on health professionals and saves the industry quite a lot of money.[7]

Managing Medications:
Some AI-based apps monitor the usage of drugs by a patient in real time. These apps use a webcam to autonomously make sure whether the patients are taking medicines according to their prescription or not. It helps patients manage their health conditions. Patients with serious health conditions and those who often fail to follow doctor's advice can get maximum benefits from such apps. [8]

CHALLENGES & LIMITATIONS:

The complexities of drug design and development provide a natural target for the application of the methods and technologies of artificial intelligence to achieve greater success at potentially lower cost and shorter time to market [9]. To date, however, the results have been more incremental than disruptive but hold much promise for the future. The technology alone, however, does not directly address some critical challenges which, in turn, present potential opportunities that could enhance clinical and commercial success.[10]

AI in risk-based monitoring – a clinical trial monitoring technique that fulfills regulatory requirements but moves away from 100% source data monitoring – can significantly improve the conduct of clinical trials in all phases. In Phase II and III clinical trials, AI can identify and predict human-relevant disease biomarkers to select and recruit specific patient populations, which would increase the success rate of clinical trials.[12]

The entire success of AI depends on the availability of a substantial amount of data because these data are used for the subsequent training provided to the system. Access to data from various database providers can incur extra costs to a company, and the data should also be reliable and high quality to ensure accurate result prediction [9]. Other challenges that prevent full-fledged adoption of AI in the pharmaceutical industry include the lack of skilled personnel to operate AI-based platforms, limited budget for small organizations, apprehension of replacing humans leading to job loss, skepticism about the data generated by AI, and the black box phenomenon.[11]

FUTURE LEEWAY:

The main potential of AI in the pharmaceutical industry is to reduce costs and increase efficiency. Extensive research has demonstrated that dynamic learning can distinguish profoundly exact AI models while using half or less information than traditional AI and information subsampling approaches [4]. Although the reason for this increased productivity is not fully understood, it appears that reduced repetition and predisposition, as well as gaining more significant information to traverse choice limits, are key components in this improved execution. As a result, without taking into account the expected mechanical overhead for actually carrying out dynamic learning efforts, screening expenses appear to be reduced by up to 90%.[10]
Machine Learning Techniques can manage complex analyses with huge, heterogeneous, and high-

dimensional information collections with no manual input, which has proved helpful in writing business applications.[9]

CONCLUSIONS:

AI offers significant technological advances that may represent a paradigm shift in drug discovery and, ultimately, clinical development. We believe that passages that now feel like a sea change will rapidly become table stakes in discovery speed, novelty, and commercial potential. Many use cases are already maturing to the point where the impact is well understood. Acting boldly, with a clearly articulated strategy that resets a few key opportunities in your discovery efforts, can set you on the right path. The Pharmaceutical companies that move quickly will be the biggest winners. Another problem is occupational and skillset immobility: many people currently working in the pharmaceutical industry do not have the necessary skills or the qualifications needed to operate AI systems. Many people are proficient in data science, and others in molecular chemistry and biology, but few are experts in both, with the right combination of skills to apply AI in pharmaceutical drug discovery. A knowledge of the underlying chemistry is required to generate appropriate algorithms, and vice versa. Artificial intelligence methods hold great promise towards these goals but their success will depend on aligning the right question with the right technology.

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