A review on Artificial Intelligence (AI) in Pharmaceutical Sector

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Abstract- **Artificial Intelligence (AI) has been transforming the practice of drug discovery in the past decade. Various AI techniques have been used in many drug discovery applications, such as virtual screeningand drug design. In this survey, we first give an overview on drug discovery and discuss related applications, which can be reduced to two major tasks, i.e., molecular property prediction and molecule generation. We then present common data resources, molecule representations and benchmark platforms. As a major part of the survey, AI techniques are dissected into model architectures and learning paradigms. To reflect the technical development of AI in drug discovery over the years, the surveyed works are organized chronologically. We expect that this survey provides a comprehensive review on AI in drug discovery. We also provide a GitHub repository with a collection of papers (and codes, if applicable) as a learning resource, which is regularly updated. Artificial intelligence has the potential to revolutionize the drug discovery process, offeringimproved efficiency, accuracy, and speed. However, the successful application of AI isdependent on the availability of high-quality data, the addressing of ethical concerns, and therecognition of the limitations of AI-based approaches. In this article, the benefits, challenges anddrawbacksof AI in this field are reviewed, and possible strategies and approaches for overcoming the present obstacles are proposed. The use of data augmentation, explainable AI, and the integration of AI with traditional experimental methods, as well as the potential advantages of AI in pharmaceutical research are also discussed. Overall, this review highlights the potential of AI in drug discovery and provides insights into the challenges and opportunities for realizing its potential in this field.**

Keywords: **Artificial Intelligence, drug discovery, clinical trial, QA and QC.**

INTRODUCTION

The developments in drug discovery have changed the practice of medicine tremendously that converting once fatal diseases into a kind of routine therapeutic exercises. One reason of this medicinal advancement has been an enhancement in the methods of developing and testing new drugs.A new drug usually does not imitate an existing drug in chemical structure that necessitates the discovery of a new molecule.

The new molecules are mostly found by the public sector as universities and research centers while the development of a new medicine, is usually done by industrial laboratories due to the requirement of very expensive chemicals, pharmacologic and toxicological screening and thorough testing. Due to these obstacles, therefore, the recent advancements are ascribed to the pharmaceutical industry asa pharma with its multibillion-dollar corporation that is devoted to drug development and marketing.Development of a new drug is very lengthy and highly expensive process since only, pre-clinical, pharmacokinetic, pharmacodynamic and toxicological studies include a multitude of *in-silico*, *in- vitro*, *in-vivo* experimentations that traditionally last in average 4 years. The further potential drug is subjected to a series of experimentation and characterization known as drug screening.

A variety ofbiologic assays at the molecular, cellular, organ, and whole animal levels are used to define the activity and selectivity of the drug. Naturally, the type and number of initial screening tests dependon the pharmacologic goal. For instance, anti-infective drugs should be tested first against a numberof infectious organisms, hypoglycemic drugs for their ability to lower blood sugar, etc. Nevertheless, the molecule is usually studied for a broad array of actions to establish the specificity of the drug. This kind of testing demonstrates the toxic effects. In addition, this may reveal a previously unsuspected beneficial therapeutic action. The selection of molecules for further study is usually conducted in animal models of human disease. These very lengthy and very expensive procedures have to be modified and if possible, to be simplified. Here lies the importance of AI technology in drug development that is demonstrated by its present and the potentials of futureapplications.

The present article is not intended to cover all the current applicability of AI in new drug development that is a highly sophisticated process. This process needs usually highly trained teams that are setup by a pharma including medicinal chemists, pharmacologists, toxicologists, computer experts and many other specialists in clinical area. The aim of the present article is to provide few published examples that reveal the power of the computer-assisted drug discovery

process to demonstrate the successful applications of AI technology. Moreover, we address the situation of drug repositioning (repurposing) in clinicalapplications through the use of AI technology.

ARTIFICIAL INTELLIGENCE IN PHARMA INDUSTRY

Recently, AI technology becomes a really fundamental a part of industry for the useful applications in many technical and research fields. The emergent initiative of accepting the applications of AI technology in pharmacy including drug discovery, drug delivery formulation development and otherhealthcare applications have already been shifted from hype to hope.[1,2] Pharmaceutical Industry can accelerate innovation by using technological advancements. The recent technological advancement that involves mind would be AI, development of computer systems ready to perform tasks normally requiring human intelligence, like seeing, speech recognition, decision-making, and translation between languages. With humongous data available during this domain, AI are often of real help in analyzing the information and presenting results that may analysis in higher cognitive process, saving Human effort, time, money and thus help save Lives. Epidermic outbreak prediction;using Machine Learning /Artificial Intelligence one can study the history of epidemic outbreak, analyses the social media activity and predict where and when epidermic can affect with considerable accuracy.[3,4] The current drug discovery process must shift dramatically so as to satisfy needs of bothsociety and patients within the 21st century. Pharmaceutical industry can accelerate innovationby using technological advancements. Pharmacy is one among the few top domains which might benefitthe foremost from emergence of computer science, since its direct impact would beaugmenting health.[5,6,7]

Artificial Intelligence focuses in producing intelligent modelling, which helps in imagining knowledge, cracking problems and higher cognitive process. Recently, AI plays a crucial role in various fields of pharmacy like drug discovery, drug delivery formulation development, poly pharmacology, hospital pharmacy, etc. AI technological approaches believe like kith and kin imagining knowledge, cracking problems and higher cognitive process. As a result of the uses of AI approaches, the designing of the new hypotheses, strategies, prediction and analyses of assorted associated factors can easily be finished the ability of less time consumption and inexpensiveness. Artificial Intelligence and machine learning are playing a critical role within the pharmaceutical industry and consumer healthcare business. From augmented intelligence applications like disease identification and diagnosis, helping identify patients for clinical trials, drug manufacturing, and predictive forecasting, these technologies have proven critical. Recently Mr. Subroto Mukherjee, Head of Innovation and Emerging Technology, Glaxo SmithKline discussed on how AI and ML are being applied to the pharmaceutical industry.[8,9,10]

ARTIFICIAL INTELLIGENCE IN DRUG DISCOVERY

Drug discovery is a time-consuming process, with low success rates. On average, developing a brand-new drug costs 2.6 billion US dollars and may take over 10 years. Moreover, the success rate of launching a drug to promote from run| phase -I| clinical trial| clinical test. Clinical trial is daunting, but 10%. within the past decade, the practice of drug discovery has been undergoing radical transformations driven by the rapid development in computing (AI).[11] Popular applications of AI in drug discovery include virtual screening, *de novo* drug design, retrosynthesis and reaction prediction, and de novo protein design, among others, which may be reduced to 2 categories, i.e., predictive and generative tasks.[12] To power these AI applications, a good range of AI techniques are involved, with model architectures evolving from traditional machine learning models to deep neural networks, like convolutional neural networks, recurrent neural networks, graph neural networks and transformers, etc. Learning paradigms also shift from supervised learning to self-supervised learning and reinforcement learning.[13,14,15]

Drug discovery is initial stage of biopharma research and development and involves the identification and optimization of potential new drugs and a preclinical *in-vivo* validation through cell assays and animal models. Successful candidates that meet the regulatory requirements applied to drug discovery get in the trial phase, where they're tested for efficacy and safety in humans.[16] Our next report within the series examines the impact AI has on clinical trials (Intelligent clinical trials: Transforming through engagement). The invention of latest therapeutics involved the extraction of ingredients from natural products and basic research to seek out potential treatments. The advantages of small molecules include simple manufacturing and administration routes, low specificity and a stable period of time, meaning they're safe and effective for giant groups of individuals. However, low specificity may cause side effects, reducing the probabilities of success in clinical trials. Since the 1990s, scientific and technological advances have led to the invention oflarger, more complex, biological therapeutics referred to as biologics. In contrast to chemically synthesized small molecules, biologics are produced or isolated from living organisms and include a large range of products like allergenic, antisense drugs, blood and blood components, recombinanttherapeutic DNA and proteins, and vaccines. Biologics are highly specific to their target and have invoked high levels of media and investor interest because of their innovative techniques and potential to cure previouslyuntreatable diseases.

The applications of AI in drug discovery process concerns the utilization of chemical space. In
fact, the chemical space offers the phase for the identification of recent molecules since it's achievable to computationally itemize the required molecules. Additionally, the machine learning and related predictive tools also

help for the identifications of target-specific effective molecules. The method of choosing a successful new drug molecule from lots of abundance of pharmacologicalactive chemical entities is that the toughest a part of the entire phenomenon.[17,18] Benevolent AI is employed for the aim of processing fewer molecules with way more surety about their activity. during this regard, de novo design necessitates the understanding of chemical science for the synthesis of in-silico molecules and also the virtual screening modeling that perform because the replacements for several biochemical still as biological testing to live the efficiency yet as toxicity profiles. The aim of de novo design within the drug discovery is that the invention of newer active molecules without the uses of reference molecules. Finally, the active learning algorithms permit theinvention of latest molecules with the potential actions against the target-setting of diseases or disorders. Several in silico methods for the choice of profiles like ligand-based design approaches or molecular structure-based design approaches could also be employed together with the accessible information on the little molecule modulator probes or the features of structural biology. In silico molecules is obtaining the subsequent generation AI. There are various proposals and software solutions accessible for it. This design isn't useful in drug discovery; but it's connected to the generation of components possessing difficulty in synthesis.[1,18,19,20]

Drug discovery often takes a protracted time to check compounds against samples of diseased cells. Finding compounds that are biologically active and are worth investigating further requires even more analysis. To hurry up this screening process, Novartis research teams use images from machinelearning algorithms to predict which untested compounds can be worth exploring in additional details. As computers are far quicker compared to traditional human analysis and laboratory experiments in uncovering new data sets, new and effective drugs may be made available sooner, while also reducing the operational costs related to the manual investigation of every compound. This AI initiative by the highest biopharmaceutical companies include:

a. Mobile platform to enhance health outcomes – the ability to recommend patients by means of realtime data collection and thus improve patient outcomes.

b. Drug discovery- pharma companies in conjunction with software companies try to implement theforemost cutting – edge technologies within the costly and extensive process of drug discovery.[3,21]

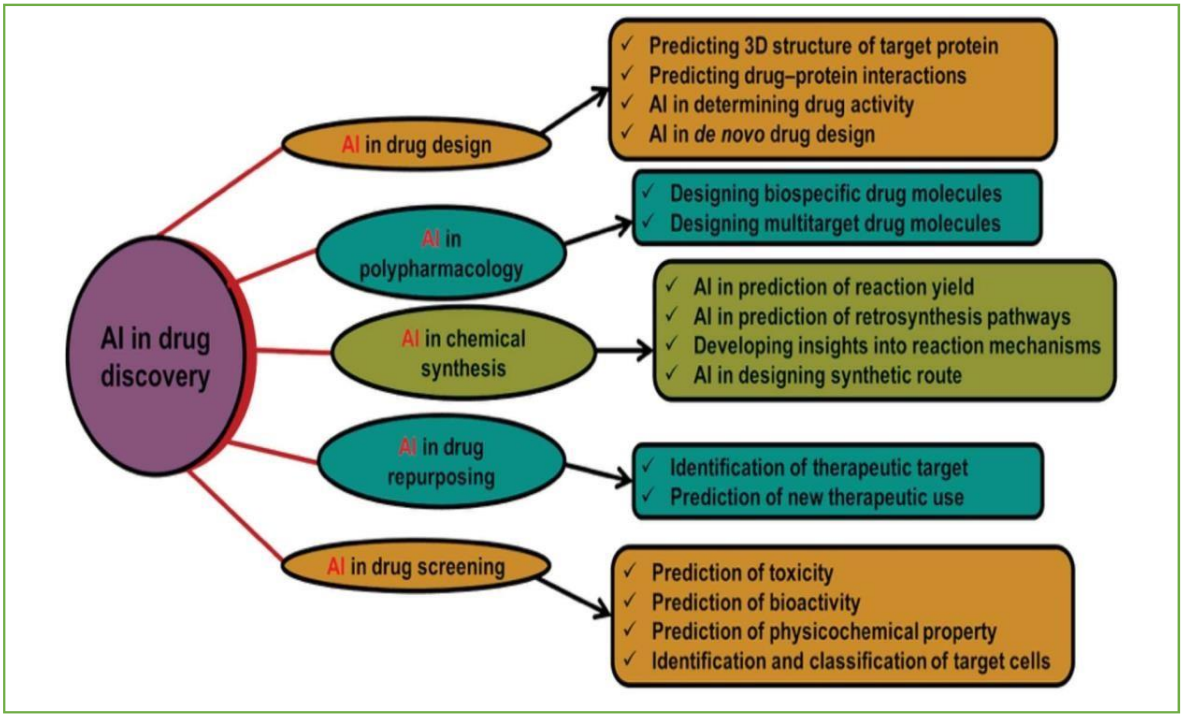


Fig.2: artificial intelligence (ai) in drug discovery AI has the potential to help in several areas of drug discovery, including drug design, chemical synthesis, drug screening, polypharmacology, anddrug repurposing.

Artificial Intelligence in Drug Development

Pre-clinical testing through clinical trials is the first of two main stages in the development of new drugs;the second is submitting the product for regulatory approval. More recently, AI has entered the developmental stages. Its main purpose is to facilitate the gathering, organizing, and analysis of "big data" in order to enhance trial performance and gain regulatory approval. In order to conduct clinical trials, test sites and staff must be identified and evaluated. These criteria include having access to a sufficient number of trial participants, clinical competency, administrative and technical support that canmeet performance standards, and the ability to identify potential trial participants from clinical

records. AI techniques are being used to evaluate possible sites for their past compliance with crucial enrollment requirements and screening records, as well as to analyze electronic health information to find possible participants who match trial inclusion/exclusion criteria.

Applications of artificial intelligence

Fig3: Artificial intelligence (AI) is being used in various areas of the pharmaceutical sector, rangingfrom drug discovery to pharmaceutical product management.

Artificial Intelligence in Clinical Trial Design

Clinical trials take 6-7 years and a significant financial investment to establish the safety and efficacy of a medicinal product in people for a specific illness condition. However, just one out of every ten molecules that enter these trials is approved, resulting in a substantial loss for the industry.[22] These failures might occur as a result of poor patient selection, a lack of technological needs, or a lack of infrastructure. However, with the large amount of digital medical data available, these failures can be decreased by the use of AI.[23]

Enrolling participants consumes one-third of the clinical study timeline. The enrollment of suitable patients ensures the success of a clinical study, which otherwise results in 86% of failure cases.[24] AI can help in the selection of a specific diseased population for enrollment in Phase II and III clinical trials by applying patient-specific genome-exposome profile analysis, which can aid in the early prediction of possible therapeutic targets in the patients chosen.[23,25] Preclinical molecule discovery and prediction of lead compounds prior to the start of clinical trials using other aspects of AI, such as predictive ML and other reasoning techniques, aid in the early prediction of leadmolecules that would pass clinical trials with consideration of the selected patient population.[25] Drop out of patients from clinical trials accounts for 30% of clinical trial failure, resulting inadditional recruiting requirements for the trial's completion, resulting in a waste of time and money.This can be avoided by closely monitoring the patients and assisting them in adhering to the clinicaltrial procedure.[24] AI Cure developed mobile software to track regular medication intake bypatients with schizophrenia in a Phase II trial, which boosted patient adherence by 25%, assuring the clinical trial's successful completion.[23]

Artificial Intelligence in Quality Control and Quality Assurance

A balance of different criteria must be achieved throughout the production of the desired productfrom raw materials. It takes human intervention to maintain batch-to-batch consistency and conduct

quality control testing on the products. This illustrates the need for AI implementation at this time and may not be the optimal strategy in every situation.[26] By implementing a "Quality by Design" approach, the FDA modified Current Good Manufacturing Practices (cGMP) in order to better understand the crucial process and precise standards that determine the ultimate quality of the pharmaceutical product.[27]

Gams et al. created decision trees using a combination of human effort and AI by analyzed preliminary data from production batches. The operators further turned them intorules and examinedthem in order to direct the manufacturing cycle going forward.[28] Goh et al. used ANN to analyze thedissolution profile of theophylline pellets, a sign of batch-to-batch consistency, and they found that it accurately predicted the dissolution of the tested formulation withan error of only 8%.[29]

AI can also be used to regulate in-line manufacturing processes in order to attain the target product standard.[27] The freeze-drying process is monitored using an ANN-based method that employs a combination of self-adaptive evolution, local search, and backpropagation algorithms. This can be utilized to anticipate the temperature and desiccated-cake thickness at a future time point (t + t) fora specific set of operating circumstances, thereby assisting in the quality control of the final product.An automated data input platform, such as an Electronic Lab Notebook, combined with advanced, intelligent algorithms can ensure product quality.[30] Furthermore, data mining and various knowledge discovery techniques in the Total Quality Management expert system can be employed as valuable approaches in making difficult judgments, resulting in the development of new technologies for intelligent quality control.[31]

Artificial Intelligence in Pharmaceutical Manufacturing

Modern manufacturing systems are attempting to impart human knowledge to machines as a result of the growing complexity of production processes, as well as the growing desire for efficiency and greater product quality.[32] The pharmaceutical industry may profit from the use of AI in manufacturing. Utilizing the automation of many pharmaceutical activities, tools like computational fluid dynamics (CFD) use Reynolds-Averaged Navier-Stokes solvers technology to examine the effects of agitation and stress levels in various pieces of equipment (such stirred tanks). Similar systems, such big eddy simulations and direct numerical simulations, use sophisticated techniques toaddress challenging flow problems in manufacturing.[26]

The innovative Computer platform aids digital automation for molecule synthesis and manufacture by including numerous chemical codes and working through the use of a scripting language known as Chemical Assembly.[33] With yield and purity very similar to manual synthesis, it has been used to successfully synthesize and produce sildenafil, diphenhydramine hydrochloride, and rufinamide.[34] AI technology can effectively complete the estimated granulation in granulators with capacities ranging from 25 to 600.[35] Neuro-fuzzy logic and technology were used to correlate key factors withtheir answers. In order to anticipate the proportion of granulation fluid to be supplied, the necessary speed, and the diameter of the impeller in both geometrically identical and dissimilar granulators, they developed a polynomial equation.[36]

Artificial Intelligence in Pharmaceutical Product ManagementArtificial Intelligence in Market Positioning

Market positioning is the process of establishing a product's identity in the market in order to persuade customers to acquire it, making it a key component in almost all business strategies for enterprises to build their own distinct identity.[37,38] This strategy was employed in the promotion of the pioneer brandViagra, which was marketed not only for the treatment of erectile dysfunction in males, but alsofor other disorders impacting quality of life.[39]

Companies can now achieve natural brand recognition in the public realm with the use of technology and e-commerce as a platform. Companies use search engines as one of the technology platforms to get a prominent place in online marketing and aid in product positioning, as affirmed by the Internet Advertising Bureau. Companies are constantly attempting to rank their websites higher than those of other companies in order to gain attention for their brand in a short amount of time.[40] Other techniques,such as statistical analysis methods and particle swarm optimization algorithms (introduced by Eberhart and Kennedy in 1995) used in conjunction with NNs, produced a more accurate picture of markets. They can assist in determining the product's marketing strategy based onaccurate consumer demand prediction.[41]

Artificial Intelligence Market Prediction and Analysis

A company's success is determined by the constant expansion and growth of its business. Despite having access to large funding, R&D production in the pharmaceutical business is declining due to companies' failure to adopt new marketing technologies.[42] The 'Fourth Industrial Revolution' in digitaltechnologies is assisting innovative digitalized marketing through a multicriteria decision- making approach, which collects and analyses statistical and mathematical data and implements human inferences to make AI-based decision-making models explore new marketing methodology.[43]

AI also aided in a full examination of a product's core requirements from the customer's perspective,as well as analyzing market demand, which aids in decision-making using prediction tools. It can also forecast sales and conduct market research. AI-based software engages customers and raises physicianawareness by providing adverts that connect them

to the product site with a single click.[44] Furthermore,these strategies employ natural language processing tools to examine keywords enteredby clients and associate them with the likelihood of purchasing the goods.[45,46]
Several business-to-business (B2B) companies have introduced self-service solutions that enable free browsing of health items, which can be easily located by providing specifications, placing orders, and tracking their shipping. Pharmaceutical companies are also launching online programmers such as 1 mg, Medline, Net meds, and Ask Apollo to meet patients' unmet requirements. Market prediction is also important for various pharmaceutical distribution organizations that can apply AI in the sector, such as 'Business clever Smart Sales Prediction Analysis', which employs a combination of time seriesforecasting and real-time application. This enables pharmaceutical companies to forecast product salesin advance, avoiding the expenditures of excess stock or client loss due to shortages.[47]

Artificial intelligence In Advancing Pharmaceutical Product Development

The subsequent inclusion of a novel therapeutic molecule into an appropriate dosage form with the requisite delivery properties is necessary. The traditional method of trial and error can be replaced in this area by AI.[48] With the use of QSPR, a variety of computational methods can be used to overcome concerns with stability, dissolution, porosity, and other aspects of formulation design.[49] Decision- support tools operate through a feedback mechanism to monitor the entire process and sporadically adjust it.[50] They employ rule-based systems to choose the type, nature, and quantity of the excipients based on the physicochemical parameters of the medicine.
Guo et al. combined expert systems (ES) and artificial neural networks (ANN) to produce a hybrid method for the production of piroxicam direct-filling hard gelatin capsules that adhere to the parametersof its dissolution profile. Based on the input parameters, the MODEL EXPERT SYSTEM (MES) generates decisions and suggestions for formulation development. Contrarily, ANN makes formulation development simple by using backpropagation learning to connect formulation parameters to the intended response, which is jointly regulated by the control module.[48]
The influence of the powder's flow property on the die-filling and tablet compression process has been studied using a variety of mathematical tools, including computational fluid dynamics (CFD), discrete element modelling (DEM), and the Finite Element Method.[26,51] The effect of tablet geometry on its dissolution profile can also be studied using CFD. The quick manufacture of pharmaceutical items maybenefit greatly from the integration of these mathematical models with AI.[52]

Artificial Intelligence in natural product-inspired drug discovery

Drug discovery is a process of identifying active compounds with therapeutic effects on the intended diseases. Although a high throughput screening technique can scan thousands of different compounds one at a time, it is still time-consuming and costly.[53] To address these challenges, AI techniques have been applied to nearly all aspects of drug discovery. The applications of AI to natural product- inspired drug discovery, such as de novo drug design, target structure prediction, DTI prediction, and drug- target binding affinity prediction, are illustrated in fig.4.

De novo drug design

De novo drug design refers to the process of generating novel druglike compounds without a starting template. Although conventional structure-based and ligand-based drug design methods have enhanced the discovery of small-molecule drug candidates, they respectively rely on knowledge about the active site of a biological target or the pharmacophores of a known active binder,[54] hindering theirapplications to modern drug discovery. The boom of AI techniques has offered new opportunities to denovo drug design and accelerated the drug discovery process.
In recent years, various deep learning-based models have been proposed for de novo drug design, such as the reinforcement learning based model Release,[55] the encoder-decoder-based model Chemed, the GAN-based model Graph INVENT and the RNN-based model MolRNN. Another key point of de novo drug design is molecular representation. SMILES, fingerprint, molecular graph, and 3D geometry have been used as input of deep learning algorithms.

Target structure prediction

Most drug targets are proteins that play important roles in enzymatic activities, cell signaling, and cell- cell transduction. The functions of proteins are determined by their structures. Although conventional experimental techniques, such as X-ray crystallography, cryogenic electron microscopy, and nuclear magnetic resonance spectroscopy, have been proposed to determine protein structures, they are still time-consuming and costly. As reported, experimental techniques have only deciphered the structures of 100,000 unique proteins, which account for only a small part of known proteins.[56] Therefore, developing novel methods to fill the gap between the number of protein sequences and known protein structures is an urgent need.[57]
With the rapid growth of computational power and the breakthroughs of AI techniques, many computational approaches have been proposed for protein structure prediction. The basic schematics of computational protein structure prediction models are presented in the right upper corner of fig.4 The neural network-based Alpha Fold method developed by DeepMind is the best-performing method, and it is able to predict the 3D structures of proteins from their amino acid sequences and achieve accuracies competitive with experiments.

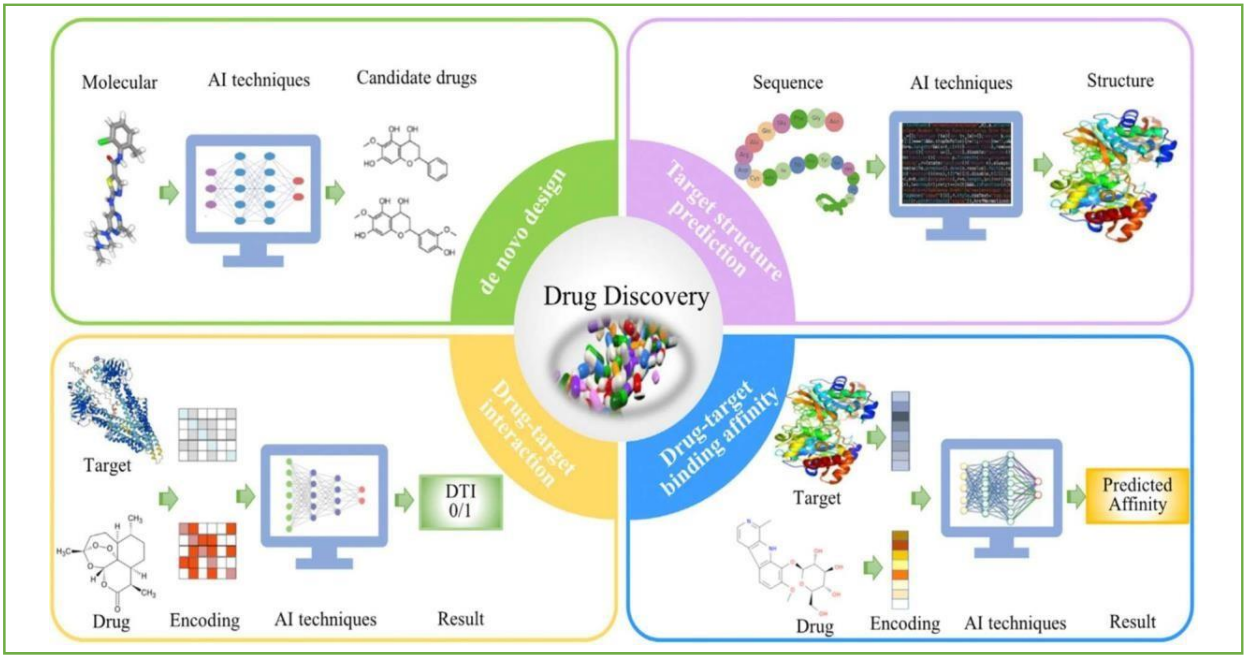
DTI prediction

DTI prediction refers to the interaction between chemical compounds and protein targets in living organisms.[58] DTI prediction is an essential process for drug discovery. Hence, experimental methodshave been used to determine DTI, such as co-immunoprecipitation, phage display technology, and yeasttwo- hybrid.[59] However, these wet laboratory techniques are time-consuming when they are used to predict DTI. Recently, the ever-increasing biological data have paved the way for the in-silico prediction of DTI. Therefore, computational methods are being increasingly used in DTI prediction.[60] These methods, whichwere summarized in a recent review, can be classified into the following categories: ligand-based methods, docking simulations, gene ontology-based methods, text mining-based methods, and network-based methods. Compared with other types of methods, deep learning-based methods frequently exhibit better performance in DTI prediction. The common workflow of the deep learning-based DTI prediction method is illustrated at the left bottom corner of fig.4 First, compounds and proteins are encoded by usingtheir corresponding features. Then, the featureembedding of the compounds and proteins is used as the input of deep learning methods. In accordancewith this strategy, models based on deep belief neural network, CNN, and multiple layer perceptron have been proposed for drug-protein interaction prediction, considerably facilitating drug discovery.

Drug-target binding affinity prediction

In most cases, DTI prediction is regarded as a binary classification problem, but binding affinity betweenadrug and its target is disregarded.[58] Binding affinity reflects the strength of drug-target pair interactions, and it is considerably informative for drug discovery. Although binding affinity can be experimentally determined by measuring dissociation and inhibition constants, the time cost and financial expenses of these procedures are extremely high. Therefore, developing computational methods for predicting bindingaffinity is necessary. In 2018, Ozturk et al. proposed the first deep learning model, called Deep DTA, for predicting binding affinity between drugs and their targets.[61] In Deep DTA, the drug and the target were encoded using SMILES and amino acid letters, respectively,which were then used as input for CNN. The basic framework of Deep DTA is shown at the right bottom corner of fig.4 The comparative results demonstrated that Deep DTA suppressed KronRLS and SimBoost for drug-target binding affinity prediction. Inspired by Deep DTA, a series of deep learning-based models has been sequentially proposed,such as Wide DTA and Deep Affinity, which have become useful tools in drug discovery.[62]

Fig: AI techniques for natural product-inspired drug discovery



The present status of Artificial Intelligence in drug development

Computer intelligence, sometimes referred to as artificial intelligence, is machine intelligence. AI is specifically any method that makes it possible for computers to simulate the functioning of the humanbrain and can be applied to the entire process of finding and developing new drugs. By evaluating therapeutically relevant data that directs the discovery of new prospective targets, AI in information synthesis refers to applications directly involved in drug development optimization. Potential medications' molecular structures can be created and optimized with the assistance of AI in drug creation. Furthermore, knowing how the particular structures of proteins dictate their functions in health and malfunction in illness is a crucial first step in the design of new drugs. Two recent studies discussed the application of AI techniques for three-dimensional

Challenges and limitations of using AI in drug discovery

Despite the potential benefits of AI in drug discovery, several challenges and limitations that must be considered. One of the key challenges is the availability of suitable data.[63] AI-based approaches typically require a large volume of information to be trained. In many cases, the amount of data accessible may be limited, or the data may be of low quality or inconsistent, which can affect the accuracy and reliability of the results.[64] Another challenge is the ethical considerations , since AI- based approaches may raise concerns about fairness and bias (see next section).[65] For example, if the data used to train a ML algorithm is biased or unrepresentative, the resulting predictions may be inaccurate or unfair.[66] Ensuring the ethical and fair use of AI for the development of new therapeutic compounds is an important consideration that must be addressed.[67] Several strategies and approaches that can be used to overcome the obstacles faced by AI in chemical medicine. One approach is the use of data augmentation, which involves the generation of synthetic data tosupplement existing datasets. This can increase the quantity and diversity of data available for trainingML algorithms, improving the accuracy and reliability of the results.[68] Another approach is the useof explainable AI (XAI) methods, which aim to provide interpretable and transparent explanations forthe predictions made by ML algorithms. This can help to address concerns about bias and fairness in AI-based approaches, and provide a better understanding of the underlying mechanisms and assumptions behind the predictions.[69]

Current AI-based approaches are not a substitute for traditional experimental methods, and they cannotreplace the expertise and experience of human researcher.[70,71] AI can only provide predictions based on the data available, and the results must be validated and interpreted by human researchers. The integration of AI with traditional experimental methods can also enhance the drug discovery process. By combining the predictive power of AI with the expertise and experience of human researchers, it is possible to optimize the drug discovery process and accelerate the development of new medications.[72]

Challenges and opportunities

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 and at potentially lower cost and shorter time to market. 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.

Target selection: How well is the disease/condition diagnosed and stratified, i.e. is the phenotype adequately defined? How comprehensive is patient stratification, i.e. clinical history, co-morbidities, lifestyle, environment, genomics, etc.? Is the target generalizable across the real-world patient population, i.e. observed diversity?

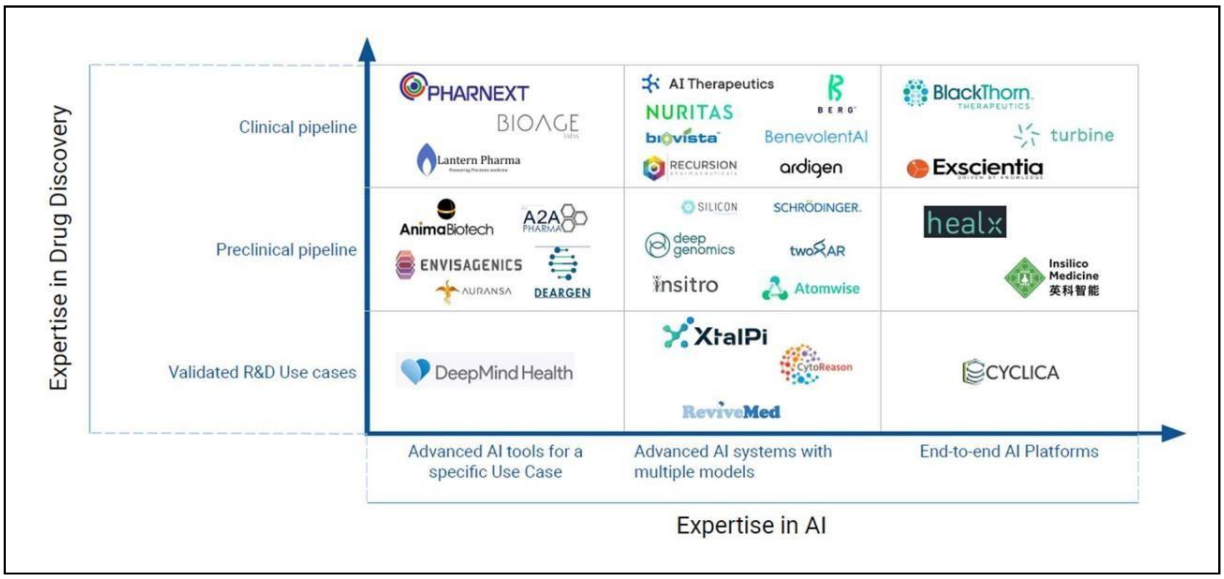
Drug design/selection: Can we "decode" deep learning to interpret results? All patients reflect comorbidities and poly-pharmacy, how are these being addressed? How well are pathway modulators being modeled as to individual targets and response?

Clinical trials: How do inclusion/exclusion criteria approximate real-world patients? How does this impact commercialization post-approval? Could disease and/or population stratification lead to shorter, more directed clinical trials?

List of first of its kind AI-based drugs.[73]

Name of the Drug andPurpose	Company	Status
DSP-1181 - treatment of obsessive-compulsive disorder (OCD).	Exscientia in collaboration with Sumitomo Dainippon Pharma	Entered phase-1 clinical trials on January 30, 2020.
EXS21546 - Immuno-oncology drug.	Exscientia in collaboration withEvotec	Entered phase-1 clinicaltrials on April 09, 2021.
DSP-0038 - For treatment of Alzheimer's disease psychosis.	Exscientia in collaboration with Sumitomo Dainippon Pharma	Entered First phase of clinical trials on May,132021.

Comparison of Top-32 Leading Al for Drug Discovery Companies Expertise inDrugDiscovery R&D / Al



CONCLUSION AND FUTURE PROSPECTIVES

The pharmaceutical industry has experienced enormous progress in a number of critical sectors since the introduction of artificial intelligence. Through the use of sophisticated computer techniques, it had completely transformed conventional methods for drug discovery and development. Large pharmaceutical companies have started utilizing these advanced technology to create customized treatment plans. In order to find new treatments for chronic and life-threatening conditions including Parkinson's disease, diabetes, Alzheimer's, obsessive-compulsive disorder, and others,

which was previously challenging with current procedures, Artificial Intelligence plays a crucial role. In light of the COVID-19 pandemic, whereby expedited medication discovery and development are imperative, the pharmaceutical industry's transition to an AI-based method is also highly useful. It made it possibleto determine which prospective treatments would have the most therapeutic value and the fewest negative effects.

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