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ROLE OF ARTIFICIAL INTELLIGENCE IN DRUG DISCOVERY AND DRUG DEVELOPMENT

Dr. Sadaf Fahim[1]

Abstract

Given that AI can assist rational drug design, assist in decision making, determine the right therapy for a patient, including personalised medicines, and manage clinical data generated and use it for future drug development, AI can be expected to play a role in the development of pharmaceutical products from the bench to the bedside. Eularis' E-VAI platform is an analytical and decision-making AI platform that uses machine learning algorithms and an intuitive user interface to create analytical roadmaps based on competitors, key stakeholders, and current market share to predict key drivers in pharmaceutical sales, allowing marketing executives to better allocate resources. Gaining market share reversed economic outlook and allowed them to plan ahead of time where to invest. The huge chemical space, which contains about 1060 compounds, encourages the discovery of numerous medicinal molecules. The lack of advanced technology, on the other hand, hinders drug development, making it a time-consuming and costly endeavour that can be addressed by applying AI. AI can distinguish hit and lead compounds, allowing for faster validation of the therapeutic target and structure design optimization. The goal of drug development is to find a therapeutically beneficial chemical for curing and treating disease. Identification of candidates, synthesis, characterisation, validation, optimization, screening, and tests for therapeutic efficacy are all part of this process. Once a molecule has been proven to be useful in these studies, it will begin the drug development cess prior to clinical trials. To create a medicine that is safe, effective, and meets all regulatory standards, the new drug development process must go through numerous stages. One of the main points of our study is that the process is long, complicated, and costly enough that multiple biological targets must be explored for any new treatment that

[1] Teacher Associate at the Chanakya National Law University (Patna).

is eventually approved for clinical use, and new research techniques may be required to investigate each one. Pharmacological discovery is a multidimensional process that include identifying a drug molecule that is therapeutically useful in the treatment and management of a disease. Typically, researchers discover novel medications by developing new perspectives on a disease process that allow researchers to construct a medicine to counteract or stop the disease's symptoms. The identification of drug candidates, synthesis, characterisation, screening, and assays for therapeutic efficacy are all part of the drug development process. Following clinical trials, if a molecule achieves favourable results in these studies, it will begin the process of drug development. Due to hefty R&D and clinical trial costs, drug discovery and development is a costly process. A single new medicine molecule takes almost 12-15 years to develop from the moment it is discovered to the time it is accessible on the market for treating patients. Each effective medicine is expected to cost between $900 million and $2 billion in research and development.

Keywords: Target Identification, Lead Optimization, Artificial Intelligence, Machine Learning, In Silico, Image screening and Clinical Testing.

Introduction

The fourth industrial revolution's machine is thought to be artificial intelligence (AI). Every industry is expected to change because of AI. The time and money needed to maintain the drug development pipeline are the main difficulties in drug research and development. The development of an anticancer treatment is predicted to cost over 2.6 billion USD and take more than ten years. Most of the money spent on the 90% of candidate therapies that fail in the last stages of drug development, between phase 1 trials and regulatory approval, is the cause of these skyrocketing prices. The cornerstone for a time of quicker, less expensive, and more effective medication development is predicted to be AI. Recent developments in AI show the potential for quick, affordable drug discovery and development. The ability of a machine to carry out actions frequently associated with intelligent creatures is generally referred to as AI. Another term for AI that involves machines using data to reason for themselves is machine learning (ML). The primary distinction between ML and AI is that ML involves the direct application of combining and analysing large, diverse data sets. Experts concur that AI will revolutionise and modify how medications are discovered in the pharmaceutical sector. AI can improve a wide range of directly and indirectly linked aspects of drug discovery and development. These include, but are not limited to, the application of AI in biomarker and target discovery, drug discovery, assay creation, and cancer categorization. To significantly speed up

R&D drug discovery, AI generally seeks to automate and optimise slow processes. A number of biotech, software, and pharmaceutical firms are also working hard to incorporate AI into the research and development of new medicines. To improve the search for immuno-oncology medicines, Pfizer joined with IBM Watson Health, an AI platform, in 2016. To find treatments for metabolic diseases, Sanofi teamed up with Ex Scientia, a spin-off from Dundee University. Genentech was purchased by Roche for $46.8 billion in 2009, giving Roche's biotechnology sector, which does not integrate AI, a solid basis. Now, Genentech and the GNS Healthcare platform are working together to uncover and validate possible novel medication candidates using machine learning. The ability of AI to diagnose diabetic macular degeneration was recently demonstrated by Genentech. Even massive, established IT corporations are funding the development of pharmaceuticals. In the 13th Critical Assessment of Structure Prediction, Alphabet subsidiary DeepMind's AlphaFold AI technology, which used genomic data to predict protein 3D structures, outperformed over 90 other companies, including Novartis and Pfizer. DeepMind's achievement with AlphaFold serves as an example of how non-healthcare businesses may contribute to and enhance the pipeline for drug discovery and development. diabetes-related macular deterioration. These investments are creating a clear picture of the significant role AI will play in drug research and development in the future. In this overview, we begin by outlining the essential elements of traditional cancer drug discovery and their shortcomings. Fundamental AI ideas are then discussed, along with historical and contemporary developments in AI and drug discovery and development. The promise and difficulties of AI in oncology are introduced lastly.

What Is Artificial Intelligence: An Understanding

In order to understand the use of artificial intelligence in discovery and development of drug, we firstly need to have a basic understanding of artificial intelligence. An Artificial Intelligence (AI) is basically a wide range of branch of computer science whose main purpose is building of smart machines which are capable enough to perform those works which primarily requires human efforts.[2] An AI simply just simulates the human intelligence by the machines and these machines are programmed in a way to think like humans and react just like humans with their actions. The term may also be applied to any machine that exhibits traits associated with a human mind such as learning and problem-solving.[3] AI is a device that perceives its environment and takes such actions which maximises its chances of successfully achieving its

[2] Artificial Intelligence, Builtin, https://builtin.com/artificial-intelligence

[3] Jake Frankenfield, *Artificial Intelligence (AI),* INVESTOPEDIA (Mar. 8, 2021), https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp

goals. Artificial Intelligence is a field of computer science which emphasizes on the creation of machines that could work and act just like humans. It aims at achieving accuracy and efficiency in human decision-making by replicating human intelligence. It could be said that it is intelligence demonstrated by machine, in contrast to the natural intelligence displayed by humans and other animals. Artificial Intelligence could be classified into two different kinds, namely, *Analytical Artificial Intelligence* and *Human-Inspired Artificial Intelligence.*

The *Analytical AI* has characteristics which are similar to that of cognitive intelligence: This refers to the natural intelligence possessed by humans and animals involving the brain to perform an intelligent activity. Analytical AI generates such logical reasoning of the functioning of the world using past experiences based on which future decisions are taken. And on the other hand, *Human AI* comprises of those elements which consists of both cognitive capacities as well as emotional intelligence in addition to such other competences needed in decision-making and interactions with others.

Depending on the usage and purpose, AI could be categorized into two types i.e., *Weak AI* and *Strong AI.* Weak AI is a system which is designed and created for any task. This type of system is also known as narrow AI as its purpose and scope is limited and can perform only certain number of functions, whereas on the flip side a Strong AI is a system with human cognitive or logical capabilities due to which it can perform such functions without human dependency and intervention. This type of system is also known as artificial general intelligence and is much broader than narrow AI due to its widespread functions and abilities. A subset of artificial intelligence is machine learning, which refers to the concept that computer programs can automatically learn from and adapt to new data without being assisted by humans. Deep learning techniques enable this automatic learning through the absorption of huge amounts of unstructured data such as text, images, or video.[4]

A. AI and conflict of its Identity

The scope of AI is very vast and huge, the systems present a range of different functions and uses which raise few ethical and moral questions. The system is not only as smart as the human who programs it, and it can perform only those functions as designed. Because the system is programmed by a human and it is he who decides what data must be used in its training, the potential for misuse and bias is very high and thus needs to be monitored closely in order to

[4] *Ibid. 2*

prevent disruption of society. This leads to the much-debated question over the personhood status of AI in society.

Personality is a very wide-ranging process and is most of the time connected to individual autonomy, but as seen in many cases human beings are not exclusively granted the status of the personhood. Many of the non-human entities have been granted the status of personhood including corporations. In the Indian scenario, there are no specific laws that states AI systems as a person. The personhood argument of AI has always been a subject of debate and research, this idea can be analyzed by looking into the definitions provided by various jurists and ideas of intelligence. According to Salmond, a person is *"any being whom the law regards as capable of having rights and duties."* Any being that is so capable is a person, whether a human being or not, and no being that is not so capable is a person, even though he may be a man. That is, no being can have rights unless such a being is also capable of interests which may be affected by the acts of others. Similarly, no being is capable of processing duties unless such a being is capable of such acts by which the interests of others may be affected. So, people are substances of which rights and duties are attributed.

The definition of "persons" brings forth a lingering question, whether AI should be given the status of personhood? AI is a machine and an inanimate object which can perform various activities and is more similar to other machines like cars, choppers etc. than other biological beings as they unlike other social beings cannot perceive the world and lack of human intelligence, ethical intelligence and moral values which are some essential characteristics of human beings. Human emotions have been categorized as an evolutionary process related to the survival of species; they are reactions to external stimulus or an expression of the thought process. Emotional intelligence is a very important part of human intelligence; these can be interdependent. Human decision-making process is highly influenced by and dependent on the value systems imbibed in humans. The debate of whether machines need to have emotions or whether they could be intelligent without emotions is highlighted with the discussion on emotional intelligence in machines. The main concerns with AI systems are that they are not equipped with the aspect of ethical or moral values. It just focuses on the shallow reflection of only looking into reducing real world complexities.

The AI system lacks the ability to investigate the feelings and circumstances of the parties involved while taking a decision and it has been seen that all the knowledge that human decision-maker applies while arriving at conclusion, can in its entirety be captured and programmed while developing a knowledge-based expert system. The domain of emotional

intelligence comprises of the aspects of self-awareness, that is the knowledge of one's own feelings and character and self-consciousness that is awareness of one's actions. These are very important aspects as with these the question on the efficiency of AI systems in this domain and the liability of the actions of AI systems arises. *Responsibility Objection*- this theory emphasizes on the fact that AI systems would inherently not be responsible while fulfilling its responsibilities and duties and thereby questions its capacity regarding the same. This theory also emphasizes on the liability of breach of trust. *Judgment Objection*- this theory focuses on the moral problems associated with AI and dilemma that arises when AI is to make decisions that are subjective in nature and related to morality.

B. The Indian Regulation of AI

The stance of India on AI can be considered to be in a primitive stage. It had been emphasized to a great extent and there have been deliberations for devising a concrete national policy on AI. The major concern being analysis of the legal dilemmas which surround AI systems. One of the major concerns that arise with this idea is the absence of legal relationship between AI systems and humans. Recent policy documents and working drafts on Artificial Intelligence issued by the Niti Aayog (or the Planning Commission under the Government of India) recognize ethical and fundamental concerns with the implementation of AI and hint towards a self-regulatory approach towards the same in coming times. In this backdrop, it is important for Artificial Intelligence (AI) and Machine Learning (ML) developers and stakeholders to understand the importance of precise self-regulatory exercises required to avoid risking legal and regulatory red flagging by government authorities in the coming future.[5] The trends in these policy documents suggest greater responsibility for developers of AI systems than just the broader known issues related to AI systems already recognized globally.

With the increasing use of AI to develop scalable business solutions companies around the world are also increasing their legal and regulatory risks. Authorities around the globe are now conscious of the issues of 'Explainability', 'Provability', 'Transparency', and 'Accountability' and 'Accessibility' associated with AI. With growing dependency upon technology and machine learning capabilities, the authorities are working extensively on preparing policy and legal frameworks for the regulation of AI. Policy Documentation states that existing laws are sufficient for tackling the challenges of AI that directly impact society.

[5] Tuhin Batra, *Self-Regulation in Artificial Intelligence: An Indian Perspective,* MONDAQ (Dec. 11, 2020), https://www.mondaq.com/india/privacy-protection/1015476/self-regulation-in-artificial-intelligence-an-indian-perspective

They are described in the documents as "System Considerations" and that the existing laws require sector-specific modifications and alignments. However, the policy documents identify a different category of challenges which indirectly impact the society such as loss in jobs, deep fakes, psychological profiling and malicious use. For challenges having indirect impact such as loss of jobs they suggest skilling, adapting legislations and regulations to harness new job opportunities. It is interesting to see that the recommendations on dealing with malicious use of AI for spreading hate or propaganda is to use the technology for proactive identification and flagging.

Policy documentation also identifies ethical challenges in AI based on their impact on the Indian society while recognizing the issues such as the 'Black Box Phenomenon', the issues of data collection without proper consent, the privacy of personal data, inherent selection bias, risk of profiling and discrimination, and non-transparent nature of certain AI solutions. They also recognize the reputational issues of public fear that companies are somehow harnessing huge consumer data and utilizing it inappropriately to gain consumer insight; and that the companies are developing large DATASETS and building unfair competitive advantage somehow.[6]

Drug discovery and drug development: How it's done?

Drug discovery is a process which aims at identifying a compound therapeutically useful in curing and treating disease. This process involves the identification of candidates, synthesis, characterization, validation, optimization, screening and assays for therapeutic efficacy. Once a compound has shown its significance in these investigations, it will initiate the process of drug development earlier to clinical trials. New drug development process must continue through several stages in order to make a medicine that is safe, effective, and has approved all regulatory requirements. One overall theme of our article is that the process is sufficiently long, complex, and expensive so that many biological targets must be considered for every new medicine ultimately approved for clinical use and new research tools may be needed to investigate each new target. From initial discovery to a marketable medicine is a long, challenging task. It takes about 12 - 15 years from discovery to the approved medicine and requires an investment of about US $1 billion. On an average, a million molecules screened but only a single is explored in late stage clinical trials and is finally made obtainable for

[6] *Ibid.* 4

patients. This article provides a brief outline of the processes of new drug discovery and development.[7]

Drug discovery is a multifaceted process, which involves identification of a drug chemical therapeutically useful in treating and management of a disease condition. Typically, researchers find out new drugs through new visions into a disease process that permit investigator to design a medicine to stopover or contrary the effects of the disease. The process of drug discovery includes the identification of drug candidates, synthesis, characterization, screening, and assays for therapeutic efficacy. When a molecule avails its satisfactory results in these investigations, it will commence the process of drug development subsequent to clinical trials. Drug discovery and development is an expensive process due to the high budgets of R&D and clinical trials. It takes almost 12-15 years to develop a single new drug molecule from the time it is discovered when it is available in market for treating patients. The average cost for research and development for each efficacious drug is likely to be $900 million to $2 billion. This figure includes the cost of the thousands of failures: For every 5,000-10,000 compounds that enter the investigation and development pipeline, ultimately only one attains approval. These statistics challenge imagination, but a brief understanding of the R&D process can explain why so many compounds don‘t make it and why it takes such a large, lengthy effort to get one medicine to patients. The Success requires immense resources the best scientific and logical minds, highly sophisticated laboratory and technology; and multifaceted project management. It also takes persistence and good fortune. Eventually, the process of drug discovery brings hope, faith and relief to billions of patients.[8] There are certain important stages which are important with respect to discovery and development of a drug. Those stages are as follows:

Target Identification

The first step in the discovery of a drug is identification of the biological origin of a disease, and the potential targets for intervention. Target identification starts with isolating the function of a possible therapeutic target (gene/nucleic acid/protein) and its role in the disease. [6] Identification of the target is followed by characterization of the molecular mechanisms addressed by the target. An ideal target should be efficacious, safe, meet clinical and commercial requirements and be ‘druggable‘. The techniques used for target identification may

[7] Deore, AB, Dhumane JR, Wagh HV, Sonawane RB, *The Stages of Drug Discovery and Development Process*, Asian Journal of Pharmaceutical Research and Development, 2019; 7(6):62-67

[8] Gashaw I, Ellinghaus P, Sommer A, Asadullah K., *What makes a good drug target Drug Discovery Today,* 2012; 17:S24-S30.

be based on principles of molecular biology, biochemistry, genetics, biophysics, or other disciplines.

Target Validation

Target validation is the process by which the expected molecular target – for example gene, protein or nucleic acid of a small molecule is certified. Target validation includes: determining the structure activity relationship (SAR) of analogy of the small molecule; generating a drug-resistant mutant of the presumed target; knockdown or over expression of the presumed target; and monitoring the known signalling systems downstream of the presumed target. Target validation is the process of demonstrating the functional role of the identified target in the disease phenotype. Whilst the validation of a drug‘s efficacy and toxicity in numerous disease-relevant cell models and animal models is extremely valuable the ultimate test is whether the drug works in a clinical setting.

Identification of Lead

A chemical lead is defined as a synthetically stable, feasible, and drug like molecule active in primary and secondary assays with acceptable specificity, affinity and selectivity for the target receptor. This requires definition of the structure activity relationship as well as determination of synthetic feasibility and preliminary evidence of in vivo efficacy and target engagement. Characteristics of a chemical lead are:

- SAR defined
- Drug ability (preliminary toxicity, hERG)
- Synthetic feasibility
- Select mechanistic assays
- In vitro assessment of drug resistance and efflux potential
- Evidence of in vivo efficacy of chemical class
- Toxicity of chemical class known based on preliminary toxicity or in silico studies

Lead Optimization

Lead optimization is the process by which a drug candidate is designed after an initial lead compound is identified. The process involves iterative series of synthesis and characterization of a potential drug to build up a representation of in what way chemical structure and activity are related in terms of interactions with its targets and its metabolism. In initial drug discovery, the resulting leads from hit-to-lead high throughput screening tests undergo lead optimization, to identify promising compounds. Potential leads are evaluated for a range of properties,

including selectivity and binding mechanisms during lead optimization, as the final step in early-stage drug discovery. The purpose of lead optimization is to maintain favourable properties in lead compounds, while improving on deficiencies in lead structure. In order to produce a pre-clinical drug candidate, the chemical structures of lead compounds (small molecules or biologics) need to be altered to improve target specificity and selectivity. Pharmacodynamics and pharmacokinetic parameters and toxicological properties are also evaluated. Labs must acquire data on the toxicity, efficacy, stability and bioavailability of leads, in order to accurately characterize the compound and establish the route of optimization. Researchers in drug discovery need rapid methods to narrow down the selection of drug candidates for this downstream selectivity profiling and further investigation. High throughput DMPK (drug metabolism and pharmacokinetics) screens have become an essential part of lead optimization, facilitating the understanding and prediction of in vivo pharmacokinetics using in vitro tests. In order to make new drugs with higher potency and safety profiles, chemical modifications to the structure of candidate drugs are made through optimization.

Product Characterization

When any new drug molecule shows a promising therapeutic activity, then the molecule is characterized by its size, shape, strength, weakness, use, toxicity, and biological activity. Early stages of pharmacological studies are helpful to characterize the mechanism of action of the compound.[9]

Formulation and Development

Pharmaceutical formulation is a stage of drug development during which the physicochemical properties of active pharmaceutical ingredients (APIs) are characterized to produce a bioavailable, stable and optimal dosage form for a specific administration route.

Pre-Clinical Testing

Pre-clinical research in drug development process involves evaluation of drug ‘s safety and efficacy in animal species that conclude to prospective human outcome. The pre-clinical trials also have to acquire approval by corresponding regulatory authorities. The regulatory authorities must ensure that trials are conducted in safe and ethical way and would give approval for only those drugs which are confirmed to be safe and effective. ICH has established a basic guideline for technical necessities of acceptable preclinical drug development. The pre-clinical trials can be conducted in two ways: General pharmacology and Toxicology.

[9] *Ibid.* 6

Pharmacology deals with the pharmacokinetic and pharmacodynamics parameters of drug. It is essential to explore unwanted pharmacological effects in suitable animal models and monitoring them in toxicological studies. Pharmacokinetic studies are very important to make known the safety and efficacy parameters in terms of absorption, distribution, metabolism and excretion. Toxicological studies of the drug can be performed by invitro and in-vivo test which evaluate the toxicological effects of the drug. In-vitro studies can be performed to inspect the direct effects on cell proliferation and phenotype. In-vivo studies can be performed for qualitative and quantitative determination of toxicological effects. As many drugs are species specific, it is essential to select appropriate animal species for toxicity study. In-vivo studies to evaluate pharmacological and toxicological actions, including mode of action, are often used to support the basis of the proposed use of the product in clinical studies.

The Investigational New Drug Process (IND)

Drug developers must file an Investigational New Drug application to FDA before commencement clinical research. In the IND application, developers must include:

- Preclinical and toxicity study data
- Drug manufacturing information
- Clinical research protocols for studies to be conducted
- Previous clinical research data (if any)
- Information about the investigator/ developer

Clinical Research

Clinical trials are conducted in people (volunteer) and intended to answer specific questions about the safety and efficacy of drugs, vaccines, other therapies, or new methods of using current treatments. Clinical trials follow a specific study protocol that is designed by the researcher or investigator or manufacturer. As the developers design the clinical study, they will consider what they want to complete for each of the different Clinical Research Phases and starts the Investigational New Drug Process (IND), a process they must go through before clinical research begins. Before a clinical trial begins, researchers review prior information about the drug to develop research questions and objectives.

New Drug Application (NDA)

A New Drug Application (NDA) expresses the full story of a drug molecule. Its purpose is to verify that a drug is safe and effective for its proposed use in the people studied. A drug developer must include all about a drug starting from preclinical data to Phase 3 trials detain

the NDA. Developers must include reports on all studies, data, and analysis. Beside with clinical trial outcomes, developers must include:

- Proposed labelling
- Safety updates
- Drug abuse information
- Patent information

Final Drug Approval (FDA)

Once FDA obtains a complete NDA then FDA team of review may require about 6 to 10 months to take a pronouncement on whether to approve the NDA. If Once FDA obtains a incomplete NDA then FDA team of review refuse the NDA. If FDA governs that a drug has been revealed to be safe and effective for its proposed use, it is then essential to work with the developer for upgrade prescribing information. This is denoted as *"labelling."* Labelling precisely defines the basis for approval and direction how to use the drug. Although, remaining issues required to be fixed before the drug to be approved for marketing. In other cases, FDA has need of additional studies. At this situation, the developer can choose whether to continue further develop mentor not. If a developer distresses with an FDA decision, there are tools for official appeal.

Application Of Artificial Intelligence In Drug Discovery And Drug Development

Involvement of AI in the development of a pharmaceutical product from the bench to the bedside can be imagined given that it can aid rational drug design; assist in decision making; determine the right therapy for a patient, including personalized medicines; and manage the clinical data generated and use it for future drug development. *E-VAI* is an analytical and decision-making AI platform developed by Eularis, which uses ML algorithms along with an easy-to-use user interface to create analytical roadmaps based on competitors, key stakeholders, and currently held market share to predict key drivers in sales of pharmaceuticals, thus helping marketing executives to allocate resources for maximum market share gain, reversing poor sales and enabled them to anticipate where to make investments. The vast chemical space, comprising $>10^{60}$ 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.[10]

[10] Vyas M., Artificial intelligence: the beginning of a new era in pharmacy profession. Asian J. Pharm. 2018; 12:72–76.

AI can recognize hit and lead compounds, and provide a quicker validation of the drug target and optimization of the drug structure design.[11]

AI and the concerned challenges

Despite its advantages, AI faces some significant data challenges, such as the scale, growth, diversity, and uncertainty of the data. The data sets available for drug development in pharmaceutical companies can involve millions of compounds, and traditional ML tools might not be able to deal with these types of data. Quantitative structure-activity relationship (QSAR)-based computational model can quickly predict large numbers of compounds or simple physicochemical parameters, such as log P or log D. However, these models are some way from the predictions of complex biological properties, such as the efficacy and adverse effects of compounds. In addition, QSAR-based models also face problems such as small training sets, experimental data error in training sets, and lack of experimental validations. To overcome these challenges, recently developed AI approaches, such as DL and relevant modelling studies, can be implemented for safety and efficacy evaluations of drug molecules based on big data modelling and analysis. In 2012, Merck supported a QSAR ML challenge to observe the advantages of DL in the drug discovery process in the pharmaceutical industry. DL models showed significant productivity compared with traditional ML approaches for 15 absorption, distribution, metabolism, excretion, and toxicity (ADMET) data sets of drug candidates.[12] The virtual chemical space is enormous and suggests a geographical map of molecules by illustrating the distributions of molecules and their properties. The idea behind the illustration of chemical space is to collect positional information about molecules within the space to search for bioactive compounds and, thus, virtual screening (VS) helps to select appropriate molecules for further testing. Several chemical spaces are open access, including PubChem, ChemBank, DrugBank, and ChemDB. Numerous *in silico* methods to virtual screen compounds from virtual chemical spaces along with structure and ligand-based approaches, provide a better profile analysis, faster elimination of nonlead compounds and selection of drug molecules, with reduced expenditure. Drug design algorithms, such as coulomb matrices and molecular fingerprint recognition, consider the physical, chemical, and toxicological profiles to select a lead compound.

[11] Mak K.-K., Pichika M.R., Artificial intelligence in drug development: present status and future prospects, Drug Discovery Today, 2019;24:773–780.

[12] Debleena Paul, Gaurav Sanap, Snehal Shenoy, Dnyaneshwar Kalyane, Kiran Kalia and Rakesh K. Tekade, Artificial Intelligence in Drug Discovery and Development, NATIONAL LIBRARY OF MEDCINE (Jan. 26, 2021), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7577280/

Various parameters, such as predictive models, the similarity of molecules, the molecule generation process, and the application of *in silico* approaches can be used to predict the desired chemical structure of a compound. Pereira presented a new system, DeepVS, for the docking of 40 receptors and 2950 ligands, which showed exceptional performance when 95 000 decoys were tested against these receptors. Another approach applied a multi-objective automated replacement algorithm to optimize the potency profile of a cyclin-dependent kinase-2 inhibitor by assessing its shape similarity, biochemical activity, and physicochemical properties.

AstraZeneca and its first step in AI

AstraZeneca is one of the globally recognised pharmaceutical industry and it is well known for manufacturing medicines for the masses and they are highly involved in Research and Development of new drugs which could be beneficial for the masses. As they are heading to future, they have decided to make certain advancements in their modes of R&D as they are now starting to involve AI into this process. They are generating and have access to more data than ever before. In fact, more data has been created in the past two years than in the entire previous history of the human race. But the value of this data can only be realised if we are able to analyse, interpret and apply it. Right across our R&D, we are using AI to help us decipher this wealth of information with the aim of:

- Gaining a better understanding of the diseases we want to treat
- Identifying new targets for novel medicines
- Recruiting for and designing better clinical trials
- Driving personalised medicine strategies
- Speeding up the way we design, develop and make new drugs

The scientists at AstraZeneca are using AI to help redefine medical science in the quest for new and better ways to discover, test and accelerate the potential medicines of tomorrow. The following sections tell just some of the stories behind how data science and AI are starting to make a difference to our R&D efforts. They are determined to advance our fundamental understanding of diseases such as cancer, respiratory disease and heart, kidney and metabolic diseases. Because by learning what causes or drives disease, we hope to find new ways to treat, prevent or even cure them.

Through data science and AI, we are uncovering new biological insights with the aim of increasing our R&D productivity. For example, we are using knowledge graphs – networks

of contextualised scientific data facts such as genes, proteins, diseases and compounds, and the relationship between them – to give scientists new insights and help overcome cognitive bias. In 2021 we selected the first two AI-generated drug targets into our portfolio, from our collaboration with Benevolent AI in Chronic Kidney Disease and Idiopathic Pulmonary Fibrosis.

Data science and AI can also help us reveal the secrets of disease in our genes. Our Centre for Genomics Research is working to analyse up to two million genomes by 2026. Alongside the gene-editing power of CRISPR to delete every gene in the genome to ask what role those genes play in biology; AstraZeneca scientists are peering inside our genetic make-up to help us better understand disease.

But the huge scale of the genome means these experiments produce a colossal amount of data. Data science and AI are at work helping us analyse and interpret the data more quickly and accurately.

Diamond v. Chakrabarty[13]

Chakrabarty (Plaintiff) developed a new species of bacterium capable of metabolizing hydrocarbons in a manner unknown in naturally occurring organisms using recombinant DNA processes. The microorganisms exhibited great promise in the treatment of oil spills. Plaintiff applied for a patent, which was denied by the Patent Office (Defendant) on the basis that the microorganisms were products of nature and therefore patentable. The Board of Appeals affirmed. The Court of Customs and Patent Appeals reversed, and the United States Supreme Court granted review. The issue of the case was may a live, man-made microorganism be patented?

The apex court was of the opinion that yes, a live, man-made microorganism is a non-naturally occurring composition and therefore may be patented. Resolution of this issue is, regardless of its philosophical implications, strictly a matter of statutory construction. The relevant statute here, 35 U.S.C. 101, defines as patentable any new and useful manufacture or composition of matter, among other things. It is a basic rule of construction that words are given their natural, ordinary meanings. There can be little doubt that microorganisms produced by recombinant DNA technology may be said to be manufactured and to be compositions of matter. For purposes of patent law, the fact they are alive is not relevant. Although it is true that naturally-

[13] 447 U.S. 303, 100 S. Ct. 2204 (1980)

occurring products may not be patented, a genetically engineered microorganism is not naturally occurring. While this Court recognizes that recombinant DNA technology is a controversial field, it is ill-equipped to balance the competing values and interests manifested therein; this is a task for Congress. Since the patent laws clearly include materials such as are at issue here within their scope, and no specific law exists to exclude it, the only appropriate holding is that recombinant DNA-produced microorganisms are patentable.

Conclusion

We all are very well-aware of the fact that in the pharmaceutical industry, most important phase is considered to be the drug discovery and drug development. This reason behind this being that the leading pharmaceutical business industry is very much dedicated in consistent research and development of new drugs so that it would help in treating the patients who are suffering with certain incurable diseases which do not have any medicine as of now. Development of a medicine takes a considerable period of time. It is not an expedite process which would take just 4-5 years, in order to come up with new medicines it involves a long period of time for R&D and after that the medicine are being tested on different levels and on different organisms so that the scientists could determine about the efficacy of the medicine and the toxicity of that particular medicine.

As the times have passed by and we are now heading to our future, this industry has also started to move ahead with time. There is a revolutionary advancement in the manufacturing industry taking place, and by manufacturing industry it would include each and every industry either it be automobiles, gadgets etc. Somewhere or the other we all have heard the term Artificial Intelligence, and this has started to make its way in pharmaceutical industry also. Certain leading pharmaceutical industries have started investing in AI which would be helpful for them in R&D of their medicines. Undoubtedly, if the AI is involved in the process of drug discovery and drug development, the process will save a lot of time and human labour and also they will help in providing a very precise way of R&D which at times human hands could also cannot achieve. But, with every pros, there comes a con. Considering the situation in India, AI will take a lot of time to flourish in a proper way. Artificial Intelligence makes progress in three phases, each of these phases are named as;

- Artificial Narrow Intelligence (ANI)
- Artificial General Intelligence (AGI)
- Artificial Super Intelligence (ASI)

Taking into consideration the Indian scenario, we are only the very first phase i.e., Artificial Narrow Intelligence in which we are just able to get a taste of what actually is an AI, we are actually not using AI in a proper way. In this phase we are yet to determine the legality and personhood of the Artificial Intelligence. We still are not clear on this issue that what would happen if there is any fault on the part of the AI machines. Taking a drug from idea to the clinic is a long diverse process, costing over 2.6 billion dollars, and takes over a decade to develop a cancer therapeutic. This is primarily due to high numbers of candidate drugs failing at late drug development stages. Advancements in AI are continually displaying the possibility of rapid low-cost drug discovery and development. As we make our way through the 2020s, it is evident the drug discovery and development will be permanently shaped by AI. Therefore, AI can very well shape the future of pharmaceutical industry.

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