AI INNOVATIONS IN DRUG DELIVERY AND PHARMACEUTICAL SCIENCES; ADVANCING THERAPY THROUGH TECHNOLOGY

Editors:
Kuldeep Vinchurkar
Sheetal Mane

Bentham Books

AI Innovations in Drug Delivery and Pharmaceutical Sciences; Advancing Therapy through Technology

Edited By

Kuldeep Vinchurkar
Department of Pharmaceutics and Pharmaceutical Technology
Krishna School of Pharmacy and Research
Drs. Kiran and Pallavi Patel Global Univeristy (KPGU)
Varnama, Vadodara, Gujarat-391240, India

&

Sheetal Mane
NMT Gujarati College of Pharmacy, Indore, M.P., India

AI Innovations in Drug Delivery and Pharmaceutical Sciences; Advancing Therapy through Technology

Editors: Kuldeep Vinchurkar and Sheetal Mane

ISBN (Online): 978-981-5305-75-3

ISBN (Print): 978-981-5305-76-0

ISBN (Paperback): 978-981-5305-77-7

First published in 2024.

need for a court order if at any point you breach any terms of this License Agreement. In no event will any delay or failure by Bentham Science Publishers in enforcing your compliance with this License Agreement constitute a waiver of any of its rights.

3. You acknowledge that you have read this License Agreement, and agree to be bound by its terms and conditions. To the extent that any other terms and conditions presented on any website of Bentham Science Publishers conflict with, or are inconsistent with, the terms and conditions set out in this License Agreement, you acknowledge that the terms and conditions set out in this License Agreement shall prevail.

Bentham Science Publishers Pte. Ltd.
80 Robinson Road #02-00
Singapore 068898
Singapore
Email: subscriptions@benthamscience.net

BENTHAM SCIENCE

CONTENTS

FOREWORD

In the vast landscape of pharmaceutical sciences, the confluence of artificial intelligence and drug delivery has emerged as a revolutionary force, redefining the boundaries of therapeutic advancements. "AI Innovations in Drug Delivery and Pharmaceutical Sciences: Advancing Therapy through Technology" stands as a beacon, guiding us through the transformative journey of technology-driven progress in healthcare.

This edited volume brings together a collection of insightful perspectives and groundbreaking research, offering a comprehensive exploration of the symbiotic relationship between artificial intelligence and pharmaceutical sciences. As we navigate the complexities of drug development, personalized medicine, and intelligent drug delivery systems, this book serves as a compass, pointing toward the future of healthcare innovation.

The esteemed editors have curated a diverse array of contributions from leading experts, scholars, and practitioners in the field. Each chapter unfolds a unique facet of the dynamic interplay between AI and pharmaceuticals, providing readers with a nuanced understanding of the challenges, opportunities, and ethical considerations that accompany this technological revolution.

The pace of change in the pharmaceutical landscape demands continuous reflection and collaboration. This volume not only reflects the current state of AI innovations but also serves as a catalyst for future explorations and breakthroughs. It is a testament to the collective commitment to advancing therapy through the seamless integration of technology.

As we embark on this intellectual journey, I commend the editors, contributors, and all those involved in bringing this book to fruition. May "AI Innovations in Drug Delivery and Pharmaceutical Sciences: Advancing Therapy through Technology" inspire and inform, contributing significantly to the ongoing dialogue in this transformative field.

Sudarshan Singh
Office of Research Administration
Chiang Mai University
Chiang Mai 50200, Thailand

PREFACE

Welcome to the forefront of transformative innovation in the intricate realms of drug delivery and pharmaceutical sciences. In this edited volume, "AI Innovations in Drug Delivery and Pharmaceutical Sciences: Advancing Therapy through Technology," we embark on an enlightening exploration into the dynamic intersection of Artificial Intelligence and healthcare. As editors, our goal is to present a compendium of cutting-edge research and insights that underscore the revolutionary impact of AI on the evolution of therapeutic interventions.

The landscape of drug delivery and pharmaceuticals is undergoing a paradigm shift, driven by the fusion of artificial intelligence and technology. This book serves as a collective effort, bringing together diverse perspectives, expertise, and research contributions from leading scholars and practitioners in the field. Each chapter is a testament to the collaborative endeavor to unravel the potential of AI in enhancing drug delivery systems, optimizing treatment regimens, and ultimately advancing the efficacy of therapeutic approaches.

The contributors to this volume are pioneers and thought leaders, each contributing a unique facet to our collective understanding of the synergies between AI and pharmaceutical sciences. From intelligent drug design and personalized medicine to the challenges and ethical considerations in AI applications, this book provides a comprehensive tapestry of the multifaceted impact of technology on the pharmaceutical landscape.

As editors, we are delighted to present this curated collection that reflects the current state of the art in AI innovations in drug delivery and pharmaceutical sciences. We believe that this book will serve as a valuable resource for researchers, students, practitioners, and anyone intrigued by the unfolding narrative of technology-driven advancements in healthcare.

We extend our gratitude to all the contributors for their scholarly endeavors and dedication to pushing the boundaries of knowledge. It is our sincere hope that this book stimulates further exploration, sparks insightful discussions, and inspires future breakthroughs in the ever-evolving field of AI and pharmaceutical sciences.

Enjoy the journey through the pages of "AI Innovations in Drug Delivery and Pharmaceutical Sciences: Advancing Therapy through Technology".

Kuldeep Vinchurkar
Department of Pharmaceutics and Pharmaceutical Technology
Krishna School of Pharmacy and Research
Drs. Kiran and Pallavi Patel Global Univeristy (KPGU)
Varnama, Vadodara, Gujarat-391240, India

&

Sheetal Mane
NMT Gujarati College of Pharmacy
Indore, M.P., India

ACKNOWLEDGEMENT

The compilation of "AI Innovations in Drug Delivery and Pharmaceutical Sciences: Advancing Therapy through Technology" has been a collaborative endeavor shaped by the dedication, expertise, and support of numerous individuals and organizations. As editors, we extend our heartfelt appreciation to all those who have played a significant role in bringing this volume to fruition.

First and foremost, we express our gratitude to the contributing authors whose insightful research and scholarly contributions have enriched the content of this book. Your commitment to advancing the frontiers of knowledge in AI and pharmaceutical sciences has been instrumental in creating a comprehensive and valuable resource.

We extend our sincere thanks to the reviewers who lent their expertise and time to ensure the quality and rigor of the chapters included in this volume. Your constructive feedback has been invaluable in refining the content and maintaining the high standards of this work.

We are grateful to the publishers and editorial team who have worked tirelessly to bring this project to fruition. Your professionalism, guidance, and commitment to excellence have been crucial in shaping the final product.

Our appreciation extends to the academic institutions and research organizations that have provided a conducive environment for the contributors to pursue their innovative research in the field of AI and pharmaceutical sciences.

Last but not least, we thank our families, friends, and colleagues for their unwavering support, encouragement, and understanding throughout the editorial process. Your belief in our vision and commitment to this project have been a source of inspiration.

This book is a collective achievement, and we acknowledge the collaborative efforts of everyone involved. It is our hope that "AI Innovations in Drug Delivery and Pharmaceutical Sciences: Advancing Therapy through Technology" contributes meaningfully to the ongoing discourse in this dynamic field.

Thank you.

List of Contributors

Anupam Mishra	Shri Rama Krishna College of Pharmacy, Satna (M.P), India
Bimlesh Kumar	School of Pharmaceutical Sciences, Lovely Professional University, Punjab-144411, Phagwara, India
Harshkumar Brahmbhatt	Department of Pharmacy, Sumandeep Vidyapeeth Deemed to be University , Vadodara, Gujarat, India
Juhi Bhadoria	Lakshmi Narain College of Pharmacy (RCP), Indore, India
Koshta A.	School of Pharmacy, Devi Ahilya Vishwavidyalaya, Indore, M.P., India
Kuldeep Vinchurkar	Department of Pharmaceutics and Pharmaceutical Technology, Krishna School of Pharmacy and Research, Drs. Kiran and Pallavi Patel Global Univeristy (KPGU), Varnama, Vadodara, Gujarat-391240, India
Koushlesh K. Mishra	Shri Rama Krishna College of Pharmacy, Satna (M.P), India
Leena Pathak	Department of Pharmacology, Jaihind College of Pharmacy, Pune, Maharashtra, India
Mihir Y. Parmar	Krishna School of Pharmacy and Research, KPGU, Vadodara, Gujarat, India
Mayur Chaurey	VNS Group of Institutions, Faculty of Pharmacy, Bhopal, M.P., India
Manoj Likhariya	Lakshmi Narain College of Pharmacy (RCP), Indore, India
Narendra Kumar Pandey	School of Pharmaceutical Sciences, Lovely Professional University, Punjab-144411, Phagwara, India
Nayany Sharma	Department of Pharmacology, Indore institute of Pharmacy, Indore, Madhya Pradesh, India
Praveen Sharma	Department of Pharmacology, Indore institute of Pharmacy, Indore, India
Pravin S. Admane	Gurunanak Technical Institute (Diploma in Pharmacy), Nari Road, Nagpur, MS., India
Priya Jain	Oxford International College, Opposite Pitra Parvat, Gandhi Nagar, Indore, M. P., India
Prashant Kumbhar	School of Pharmaceutical Sciences, Lovely Professional University, Punjab-144411, Phagwara, India
Pankaj Kumar Pandey	Lakshmi Narain College of Pharmacy (RCP), Indore, India
Rakesh E. Mutha	H. R. Patel Institute of Pharmaceutical Education and Research, Shirpur (M. S.), India
Rahul S. Tade	H. R. Patel Institute of Pharmaceutical Education and Research, Shirpur (M. S.), India
Rupali Sontakke	Department of Pharmacology, Faculty of Pharmacy, Medicaps University, Indore, Madhya Pradesh, India
Rajeev Mishra	APS University, Rewa (M.P), India
Rekha Bisht	Department of Pharmacology, Indore institute of Pharmacy, Indore, Madhya Pradesh, India

Rohit Doke	Department of Pharmacology, Jaihind College of Pharmacy, Pune, Maharashtra, India
Singh A.	Modern Institute of Pharmaceutical Sciences, Indore, M.P., India
Shaikh Gulfisha	Modern Institute of Pharmaceutical Sciences, Indore, M.P., India
Sheetal Mane	NMT Gujarati College of Pharmacy, Indore, M.P.,, India
Saloni Yadav	Acropolis Institute of Pharmaceutical Education & Research, Bypass Road Manglia Square, Indore, M. P., India
Salaj Khare	Krishna School of Pharmacy and Research, KPGU, Vadodara, Gujarat, India
Sushma Mishra	D.H. Waidhan, Singrauli (M.P), India
Vikas S. Patil	Gurunanak Technical Institute (Diploma in Pharmacy), Nari Road, Nagpur, MS., India
Vishal S. Bagul	H. R. Patel Institute of Pharmaceutical Education and Research, Shirpur (M. S.), India

CHAPTER 1

An Overview of Artificial Intelligence (AI) In Drug Delivery and Development

Rakesh E. Mutha[1], **Vishal S. Bagul**[1], **Rahul S. Tade**[1,*] and **Kuldeep Vinchurkar**[2]

[1] *H. R. Patel Institute of Pharmaceutical Education and Research, Shirpur (M. S.), India*

[2] *Department of Pharmaceutics and Pharmaceutical Technology, Krishna School of Pharmacy and Research, Drs. Kiran and Pallavi Patel Global Univeristy (KPGU), Varnama, Vadodara, Gujarat-391240, India*

Abstract: The integration of Artificial Intelligence (AI) into pharmaceutical research represents a transformative leap in drug development, addressing the challenges posed by complex diseases and traditional methodologies. In this comprehensive overview, we explore the historical evolution of AI's role in pharmaceutical research and its crucial importance in drug delivery and development. The foundational elements of AI in drug delivery and development are elucidated through an in-depth analysis of machine learning (ML) algorithms, deep learning techniques, and natural language processing in bioinformatics. These form the bedrock for understanding the subsequent chapters that unravel the emerging roles of AI in drug discovery, formulation, and delivery. An insightful examination of drug repurposing and interaction reveals AI-driven strategies, providing new therapeutic avenues. The chapters further unravel AI's impact on pharmacokinetics, pharmacodynamics, and its data-driven approaches for dose optimization. Clinical trials and patient recruitment witness a revolution through AI, optimizing design and ensuring regulatory compliance and safety. This chapter promises a holistic understanding of the symbiotic relationship between AI and pharmaceuticals, offering a roadmap for innovation and efficiency in the pursuit of advanced healthcare solutions.

Keywords: AI-based pharmacokinetics, AI-driven drug development, Artificial intelligence, Artificial neural network, Bioinformatics, Clinical trials, Deep learning, Dose optimization, Dosage customization, Drug discovery.

INTRODUCTION

The integration of artificial intelligence (AI) into pharmaceutical research has ushered in a new era of innovation and efficiency. This burgeoning field repre-

* **Corresponding author Rahul S. Tade:** H. R. Patel Institute of Pharmaceutical Education and Research, Shirpur (M. S.), India; E-mail: taderahul2011@gmail.com

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

sents a convergence of advanced computational techniques and the intricacies of drug development. As the complexity of disease continues to challenge traditional research methodologies, AI emerges as a transformative force, offering novel solutions and insights. The amalgamation of AI and pharmaceuticals not only expedites the drug discovery process but also enhances precision and efficacy in treatment strategies [1].

The primary motivation behind the incorporation of AI into pharmaceutical research lies in its ability to analyze vast datasets with unprecedented speed and accuracy. Traditional drug discovery methods often face bottlenecks in data processing, limiting the scope and pace of research. AI, equipped with ML algorithms, can discern patterns and correlations within data, accelerating the identification of potential drug candidates and streamlining the initial stages of drug development. This synthesis of computational power and pharmaceutical expertise marks a paradigm shift, allowing researchers to explore a broader landscape of possibilities [2].

HISTORICAL PERSPECTIVE AND EVOLUTION ROLE OF AI IN PHARMACEUTICAL RESEARCH

The historical trajectory of AI in pharmaceutical research is a fascinating narrative of evolution and adaptation. In its nascent stages, AI was primarily employed for basic tasks such as data organization and analysis. However, as computational capabilities advanced, AI found its niche in drug discovery. Early applications focused on the virtual screening of chemical compounds, predicting potential drug candidates with a level of efficiency previously unattainable. Over time, the role of AI in pharmaceutical research has expanded, encompassing molecular modelling, target identification, and even clinical trial optimization [3] (Table **1**).

Table 1. Historical overview of ai development in the pharmaceutical field.

Time Period	Discovery/Event	Company/Industry/Research	Significance	Refs.
1950s	Introduction of AI	Alan Turing's work on computation	Laid the theoretical foundation for AI.	[4]
1980s	Expert Systems	MYCIN system for medical diagnosis	A pioneer in using AI for medical decision-making.	[5]
1990s	Genetic Algorithms	Application in drug design and optimization	Introduced evolutionary computation for drug discovery.	[6]
2000s	Data Mining in Genomics	Use of AI for analyzing genomic data	Accelerated gene discovery and understanding of diseases.	[7]

(Table 1) cont.....

Time Period	Discovery/Event	Company/Industry/Research	Significance	Refs.
2010s	IBM Watson for Oncology	AI-driven system for cancer treatment recommendations	Personalized treatment options based on patient data.	[8]
2010s	DeepMind's AlphaFold	Predicting protein structures with AI	Revolutionized understanding of molecular biology.	[9]
2010s	Atomwise for Drug Discovery	Virtual screening using AI for drug candidates	Accelerated identification of potential drug compounds.	[10]
2010s	PathAI for Pathology	AI-powered pathology diagnostics	Enhanced accuracy and efficiency in pathology analysis.	[11]
2020s	COVID-19 Drug Discovery	AI models for rapid drug repurposing	The expeditious identification of potential treatments during the pandemic.	[12]
2020s	Synthesis of Drug Molecules	Deep generative models for drug design	Facilitated the generation of novel drug structures.	[13]
2020s	FDA Approval of AI Diagnostic	First approval of an AI-based diagnostic system	A milestone in regulatory acceptance of AI in healthcare.	[14]
2020s	AI in Vaccine Development	Application of AI for vaccine design	Played a role in expediting COVID-19 vaccine development.	[15]

The evolution of AI in pharmaceuticals is not solely technological; it is also a testament to the collaborative efforts between computer scientists, biologists, chemists, and clinicians. Interdisciplinary collaboration has been pivotal in refining AI algorithms to suit the intricate demands of pharmaceutical research. Today, AI-driven platforms not only assist in the identification of potential drug targets but also contribute significantly to the optimization of experimental design, minimizing resource utilization and expediting the transition from bench to bedside [16].

Importance of AI in Drug Delivery and Development

Traditional drug development often employs a one-size-fits-all model, but AI enables the customization of treatments based on genetic, environmental, and lifestyle factors, enhancing therapeutic outcomes. AI has emerged as a transformative force in various industries, and its impact on drug delivery and development within the pharmaceutical sector is particularly noteworthy. The

CHAPTER 2

Exploring the Fundamental Aspects of Artificial Intelligence: A Comprehensive Overview

Singh A.[1], **Shaikh Gulfisha**[1,*], **Koshta A.**[2] and **Sheetal Mane**[3]

[1] *Modern Institute of Pharmaceutical Sciences, Indore, M.P., India*

[2] *School of Pharmacy, Devi Ahilya Vishwavidyalaya, Indore, M.P., India*

[3] *NMT Gujarati College of Pharmacy Indore, M.P., India*

Abstract: Artificial Intelligence (AI) is a revolutionary technology with transformative potential, notably in the pharmaceutical sector. This abstract provides a comprehensive overview of AI's applications in pharmaceuticals, encompassing drug discovery, development, manufacturing, and healthcare. In drug discovery and development, AI expedites candidate identification and enhances safety and efficacy profiling through advanced data analysis, covering genomics, chemical structure, and clinical data. AI enables drug repurposing by unveiling hidden therapeutic connections in existing medications, reducing costs and timelines, and addressing unmet medical needs. Personalized Medicine is another AI-driven frontier, customizing treatment plans based on patient-specific data like genomics and medical history, enhancing treatment effectiveness. In Clinical Trial Optimization, AI streamlines trial design, patient recruitment, and monitoring speeding approval and reducing costs. AI automates drug manufacturing and quality control, ensuring high-quality products and preventing defects. AI aids in regulatory compliance through real-time monitoring and reporting. Ethical and legal considerations include data privacy and bias mitigation, demanding meticulous attention. Data Security is essential, considering sensitive patient data. Robust cybersecurity safeguards data integrity. In conclusion, AI promises to revolutionize the pharmaceutical sector, accelerating drug discovery, improving patient care, and enhancing manufacturing. However, successful implementation hinges on addressing ethical, legal, and security considerations, fostering collaboration among stakeholders and balancing innovation with responsibility. AI helps in enhancing productivity as well as increases the quality control of the products. In pharmaceuticals, AI also may increase the efficacy of the drug discovery process. It reduces the time of the drug discovery journey along with enhanced efficacy and efficiency of the developed products.

Keywords: Artificial Intelligence, Cybersecurity, Clinical data, Drug discovery, Personalized medicine.

* **Corresponding author Gulfisha Shaikh:** Modern Institute of Pharmaceutical Sciences, Indore, M.P. India; E-mail: gulfishashaikh76@gmail.com

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

INTRODUCTION

During the past few years, Artificial Intelligence (AI) has evolved as a force that is capable of bringing about significant changes in the fields of technology, industry, and society. The discipline of artificial intelligence (AI), which is a subfield of computer science, has rapidly developed from a theoretical concept to a practical reality with far-reaching ramifications. AI is committed to the creation of intelligent robots that are capable of emulating human-like cognitive functions [1 - 3].

The purpose of this chapter is to delve into its roots, core concepts, and the various applications that continue to revolutionize how we live and work [4]. Through a study of the fundamentals of artificial intelligence, readers will get a deeper understanding of the potentials, problems, and ethical considerations that are associated with this powerful technology [5, 6]. The main objectives of the study of Artificial Intelligence are to understand the uses and significance of AI in the pharmaceutical field starting from drug discovery to the post-marketing surveillance. The aim of this study is to identify the use of AI in enhanced accuracy in target identification.

HISTORICAL PERSPECTIVE OF AI

To comprehend the current status of Artificial Intelligence (AI), it is imperative to explore its historical roots, tracing its evolution from conceptual foundations to the sophisticated systems observable today. The narrative of AI's development is a captivating exploration marked by notable milestones and shifts in paradigm [7].

Early Philosophical Reflections: The origins of AI can be traced back to ancient philosophical musings on thought and reasoning. Early philosophers contemplated the possibility of constructing machines capable of imitating human cognitive processes, laying the groundwork for subsequent discussions on artificial intelligence [8, 9].

Rise of Computing and Formal Logic: The advent of computers in the mid-20th century provided the computational framework necessary for realizing artificial intelligence. Pioneers such as Alan Turing made significant contributions, with Turing's work on formal logic and the Turing Machine becoming foundational concepts in AI development [9 - 11].

Dartmouth Conference (1956): A pivotal moment in the history of AI occurred at the Dartmouth Conference in 1956. Recognized as the birthplace of AI, this event brought together influential figures, including John McCarthy, Marvin Minsky, Allen Newell, and Herbert A. Simon. The conference marked the formal establishment of AI as a field of study, outlining ambitious goals for creating machines that could replicate human intelligence.

Early AI Programs and Symbolic AI: In the subsequent decades, AI researchers focused on symbolic AI, developing programs capable of manipulating symbols and representing human knowledge. This period witnessed notable achievements, such as the General Problem Solver developed by Allen Newell and Herbert A. Simon [12].

The AI Winter: Despite early successes, the field encountered setbacks and funding declines in the 1970s and 1980s, a period known as the "AI winter." Unrealistic expectations, technical limitations, and funding challenges led to a temporary slowdown in AI research.

Rise of Machine Learning: The late 20th century witnessed a resurgence in AI research, driven by advancements in machine learning. Techniques such as neural networks gained prominence, contributing to breakthroughs in domains like natural language processing and pattern recognition [13].

Contemporary AI Landscape: In recent decades, AI has become an integral part of daily life, with applications ranging from virtual assistants and recommendation systems to complex decision-making in healthcare and finance [14, 15]. The integration of big data, powerful computing, and advanced algorithms has propelled AI to unprecedented levels of sophistication.

Understanding the historical trajectory of AI provides a foundation for comprehending the challenges and breakthroughs shaping its current landscape. From philosophical reflections to practical implementation, the journey of AI signifies a persistent pursuit of replicating and enhancing human intelligence [16].

So, it is clearly reflected from the history of AI that it is a long journey to reach the current scenario. It was a stepwise process by clearing the limitations of the previous studies and reaching the correct understanding and uses of AI in different perspectives.

SCOPE AND APPLICATIONS OF AI

Artificial Intelligence (AI) stands as a dynamic field with a diverse array of applications, catalyzing transformative changes across numerous industries [17]. This section delves into the far-reaching impact of AI on various domains, presenting both the opportunities and challenges inherent in its widespread adoption.

CHAPTER 3

Prospects for the Future: Artificial Intelligence in Pharmaceutical Technology

Pravin S. Admane[1,*], **Vikas S. Patil**[1] and **Kuldeep Vinchurkar**[2]

[1] *Gurunanak Technical Institute (Diploma in Pharmacy), Nari Road, Nagpur, MS., India*

[2] *Department of Pharmaceutics and Pharmaceutical Technology, Krishna School of Pharmacy and Research, Drs. Kiran and Pallavi Patel Global Univeristy (KPGU), Varnama, Vadodara, Gujarat-391240, India*

Abstract: Artificial intelligence is one of the emerging technologies being utilized in various areas in the pharmaceutical sector to optimize different process parameters, which leads to the development of novel drug delivery systems very efficiently. Astonishing evolution in AI technology and machine learning brings out transformational productivity in the formulation, drug discovery, and testing of pharmaceutical dosage forms. Artificial intelligence utilizes various computational tools and engineering technologies to fabricate varying dosage forms with high therapeutic efficacy and precision. AI algorithms efficiently analyze substantial biological data of proteomics and genomics, which allow researchers to find out the target site and also to predict the interactions with potential drug molecules. This phenomenon permits a targeted approach to drug discovery thereby enhancing the probability of effective drug approvals. Artificial Intelligence (AI) allows the development of intelligent modeling, resolving issues, and decision-making to create efficient data handling. Artificial intelligence plays a very crucial role in various pharmaceutical sectors including drug discovery, formulation and development of novel dosage forms, development of new analytical techniques, development of design of experiments, sales and marketing, quality assurance, clinical trials, hospital pharmacy, *etc.* Various AI-based tools like Artificial Neural Networks (ANNs) or Recurrent Neural Networks (RNNs) are successfully utilized in the field of drug discovery and newer drug delivery systems. Several drug discoveries are being made in pharmaceutical fields using AI technology in combination with quantitative structure-property relationship (QSPR) or quantitative structure- activity relationship (QSAR), which support evidence-based accurate and precise results. Additionally, de-novo design is employed to invent significant new drug molecules with the desired quality. AI algorithms are helpful in experimental design, which can accurately determine the pharmacokinetic parameters and toxic effect of drug molecules. They also allow the identification of impurities and the optimization of their concentration in the product to formulate an effective dosage form. AI-based technology can be applied to optimize the drug excipient ratio in the formulation of a new modified drug delivery system inc-

* **Corresponding author Pravin S. Admane:** Gurunanak Technical Institute (Diploma in Pharmacy), Nari Road, Nagpur, MS., India; E-mail: admanepravin16061987@gmail.com

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

luding sustained, delayed, or immediate release formulation. Formulation of personalized medications as per patient's need is one of the novel approaches that can be possible by the utilization of AI tools, leading to more precise rational treatment and improved patient compliance. The content incorporated further highlights more detailed information on AI tools and their wide applications in various pharmaceutical departments including drug discovery, process optimization, designing novel delivery systems, testing, pharmacokinetics/ pharmacodynamics (PK/PD) studies, *etc.*

Keywords: Artificial intelligence, Drug delivery system, Manufacturing of pharmaceutical products, Pharmaceutical field.

INTRODUCTION

Artificial Intelligence is one of the newly developed platforms nowadays used in different sectors. AI utilizes computational tools comprising software and engineering technologies to execute various complex tasks in an automated way in coordination with human intelligence [1]. AI-enabled machines are capable of understanding large volumes of data efficiently in order to identify lacunas in the current traits of any product and to design some procedures to overcome such lacunas, which will be acceptable to the society comprising new trends. The main objective of artificial intelligence is to explicate important information that identifies issues and provides better solutions. AI at present covers many areas including playing intellectual games, proving mathematical and statistical equations, writing articles, driving vehicles in crowded areas, *etc.* Apart from these, AI also plays a significant role in the healthcare system, where it is being utilized to diagnose the root cause of the disease, to plan the best treatment for patients facing chronic diseases like cancer, to be a part of robotic surgery which can help surgeons perform surgeries with more accuracy and minimal fluctuations and facilitate the latest updated information at the time of operation, to tailor personalized treatment as per patient need, and even to prognosticate patient survival rates.

AI technology allows more accurate analyses to perform any task and also to gain accurate interpretation of data using various useful statistical models in combination with computational intelligence [2]. Pharmaceutical Industries are continuously exploring research activities based on AI technology to produce effective and error-free medicines for patient use. Pharmaceutical sector has been utilizing data digitalization processes in the recent past, but there was a failure to produce more complex dosage regimens and thereby, unable to solve more complex clinical problems [3]. This problem brings the application of AI technology in pharmaceutical sectors, as it is able to analyze a large number of data and generate accurate results with increased automation [4]. A wide range of AI applications are being utilized in pharmacy including formulation and development, drug discovery, testing, and other healthcare applications. The AI tools also make it practicable to determine pharmacokinetic parameters of the drugs, *in vitro-in vivo* studies, personalized dosing, *etc.* AI technology uses a fundamental model of machine learning (ML), which utilizes various algorithms to recognize patterns as per data input. Machine Learning is also known as Deep learning (DL), which has evolved into different Artificial Neural Networks (ANNs) like Convolutional neural networks (CNNs), Deep neural networks (DNNs), and Recurrent neural networks (RNNs). Recurrent neural networks comprise a closed-loop, which has the potential to store and memorize information, like Hopfield networks and Boltzmann constants [5, 6]. On the other hand, convolutional neural networks (CNNs) use image and video processing in case of processing complex brain functions, biological system modelling, sophisticated signal processing, and pattern recognition [7].

Artificial intelligence (AI) has come into view as an evolutionary technology in the field of pharmaceutical sciences over the past few years. As the development of new drugs and dosage forms using conventional technologies is a very complex process associated with high risk and high costs, AI has been used as an extension of work in the development of novel formulations to treat a variety of diseases in a more accurate and précised manner in the consideration of patient-oriented approaches [8]. It also enhances the productivity of pharmaceutical products by reducing the time cycle and cost of development of formulation.

History of Artificial Intelligence

In the year 1943, the first work was done using AI-based technology by Warren McCulloch and Walter Pitts who put forward the model of Artificial Neurons. Later on, most research works have been performed based on AI-based pharmaceutical technology [8]. In 1950, Alan Turing, a mathematician and computer scientist developed a test called "Turing Test" to determine whether a machine can illustrate human intelligence. In 1956, an American computer scientist John McCarthy discussed AI at the Dartmouth conference. Later on, AI-based technology began to be utilized in industry to perform various activities in an efficient manner. The robot was the first industrialist to perform automated Die Casting, joining the assembly line at General Motors. During the period of the 1970s, AI was the first time applied to foster the development of "The Research Resource on Computers in Biomedicine" by Saul Amarel in 1971 at Rutgers University. In 1972, the first humanoid robot was developed in Japan as WABOT-1. Later on, the CASNET model has been developed at Rutgers University. It is a causal associational network, which was officially demonstrated in the meeting at the Academy of Ophthalmology in Las Vegas, Nevada, in 1976. It consists of three separate programs comprising model building, consultation,

CHAPTER 4

Artificial Intelligence in Community and Hospital Pharmacy

Saloni Yadav[1], **Priya Jain**[2,*], **Kuldeep Vinchurkar**[3] and **Sheetal Mane**[4]

[1] *Acropolis Institute of Pharmaceutical Education & Research, Bypass Road Manglia Square, Indore, M. P., India*

[2] *Oxford International College, Opposite Pitra Parvat, Gandhi Nagar, Indore, M. P., India*

[3] *Department of Pharmaceutics and Pharmaceutical Technology, Krishna School of Pharmacy and Research, Drs. Kiran and Pallavi Patel Global Univeristy (KPGU), Varnama, Vadodara, Gujarat-391240, India*

[4] *NMT Gujarati College of Pharmacy Indore, M.P., India*

Abstract: The integration of artificial intelligence (AI) into pharmaceutical research represents a transformative leap in drug development, addressing the challenges posed by complex diseases and traditional methodologies. In this comprehensive overview, we explore the historical evolution of AI's role in pharmaceutical research and its crucial importance in drug delivery and development. The foundational elements of AI in drug delivery and development are elucidated through an in-depth analysis of machine learning (ML) algorithms, deep learning techniques, and natural language processing in bioinformatics. These form the bedrock for understanding the subsequent chapters that unravel the emerging roles of AI in drug discovery, formulation, and delivery. An insightful examination of drug repurposing and interaction reveals AI-driven strategies, providing new therapeutic avenues. The chapters further unravel AI's impact on pharmacokinetics, pharmacodynamics, and its data-driven approaches for dose optimization. Clinical trials and patient recruitment witness a revolution through AI, optimizing design and ensuring regulatory compliance and safety. This chapter promises a holistic understanding of the symbiotic relationship between AI and pharmaceuticals, offering a roadmap for innovation and efficiency in the pursuit of advanced healthcare solutions.

Keywords: Artificial intelligence (AI), AI in healthcare, AI in drug discovery, Community pharmacy, Deep learning, Hospital pharmacy, Machine learning.

* **Corresponding author Priya Jain:** Oxford International College, Opposite Pitra Parvat, Gandhi Nagar, Indore, M. P., India; E-mail: drpriyajain14@gmail.com

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

INTRODUCTION

Artificial intelligence (AI) is the amalgamation of diverse intelligent processes and behaviours, formulated through computer models, algorithms, or a collection of guidelines that enable the machine to emulate human cognitive capabilities like learning, problem-solving, and so on [1, 2]. In its most basic form, artificial intelligence (AI) is the science and engineering that builds intelligent computers by programming them to follow algorithms or rules that simulate human cognitive processes like learning and problem-solving [3]. AI systems are capable of acting in a meaningful, intelligent, and adaptive way because they have the capacity to foresee challenges or address them as they emerge [4]. Consequently, artificial intelligence (AI) is a collection of intelligent behaviours and processes produced by computer models and algorithms rather than a single technology. AI has advanced faster recently attributable to improved computational models and algorithms, strong computers, and the availability of vast datasets. This has been particularly relevant for machine learning (ML), natural language processing (NLP), AI voice technologies, AI assistants, and robots [5]. AI is rapidly advancing in the healthcare industry and has a significant impact on automation, disease detection, and clinical decision-making. Artificial Intelligence (AI) presents the potential for further exploration in the realm of pharmaceutical and healthcare research due to its capability to analyze massive amounts of data from multiple modalities [1].

OBJECTIVES OF AI

• ***Expert system development:*** It entails developing intelligent, automated systems that advise users on what to do next.

• ***Human intelligence in computers:*** It is intended to assist computers acquire similar cognitive patterns so they can act like people and take the appropriate actions to deal with challenging circumstances.

• ***Multi-domain applications:*** AI will promote the application of various fields, including healthcare, psychology, natural sciences, ethics, and more.

Medical technology has been completely transformed by artificial intelligence (AI), which is generally defined as the branch of computer science that can handle difficult problems with a variety of applications in fields with a lot of data but little theory. To effectively address complex clinical issues, contemporary medicine has to devise methods for gathering, assessing, and applying the vast amount of information required. The establishment of AI programs intended to assist doctors in diagnosing patients, identifying treatments, and projecting outcomes has been linked to the development of medical AI. They are intended to aid in the information and knowledge processing required for work that healthcare professionals must regularly complete. Within the field of computer science, Artificial Intelligence (AI) research focuses on the following areas: Neural networks, language recognition, intelligent robotics, machine learning, image recognition, and expert systems [6].

COMPONENTS OF AI

Neural Networks

ANNs are computational tools that are computerized and imitate the nervous system in humans. They are made up of "neurons" or networks of interconnected computer processors, which can process data and represent information in parallel [7]. In 1943, McCulloch and Pitts used basic binary threshold functions to develop the first artificial neuron. Because of their power to generalize, simplify data with independent information, and evaluate non-linear data, they are a highly alluring analytical tool in the field of medicine [8].

Intelligent Robots

An intelligent robot is a machine that possesses the ability to act and make decisions. An intelligent robot's decision-making is influenced by its innate intelligence, which it acquires through machine learning or deep learning, as well as the information it receives from its input sensors while it is operating. In the 1980s, intelligent surgical robots were used. For example, in 1988, PUMA 560 was used in prostate surgery, and in 1985, it was used in neurosurgical biopsies. In 1992, ROBODOC became the first intelligent robot officially acknowledged by the US Food and Drug Administration (FDA). In orthopedic surgery, it was mostly used for hip replacement procedures. Currently, the FDA has approved three different robotic surgical systems, including the ZUES and Da Vinci, an automated endoscopic technique for optimizing robot placement. In urology, orthopaedics, stomatology, and other specialties, intelligent robots are widely used because of their accurate, sophisticated, and secure characteristics [6].

Machine Learning

In the artificial intelligence field of machine learning, it aims to develop algorithms that can automatically learn from experience, improving with each new algorithmic run. The algorithm works by identifying a pattern in the input data and using that pattern to create a model that uses the existing data to predict new data accurately. (Fig. **1**) The foundation of machine learning approaches is the discovery of patterns in massive data sets that help forecasts and the decision-making process for diagnosis and therapy planning. Machine learning technique is

CHAPTER 5

Revolutionizing Personalized Healthcare: The Diverse Applications of Artificial Intelligence in Medicine

Mihir Y. Parmar[1,*], **Salaj Khare**[1], **Harshkumar Brahmbhatt**[2] and **Mayur Chaurey**[3]

[1] *Krishna School of Pharmacy and Research, KPGU, Vadodara, Gujarat, India*

[2] *Department of Pharmacy, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India*

[3] *VNS Group of Institutions, Faculty of Pharmacy, Bhopal, M.P., India*

Abstract: The expansion of high-throughput, data-demanding biomedical research and technologies, like sequencing of DNA, imaging protocols, and wireless health observing manoeuvres, has shaped the need for quality researchers to form plans for detecting, integrating, and interpreting the major amounts of data they generate. Still, a wide variety of mathematical methods have been premeditated to accommodate the 'large data' produced by such assays, and familiarities with the use of artificial intelligence (AI) skills advise that they might be chiefly suitable. In total, the solicitation of data-intensive biomedical skills in research education has exposed that clinically humans differ widely at all levels, be it genetic, biochemical, physiological, exposure, and behavioral, especially with respect to disease progression and treatment output. This suggests that there is often a need to shape up, or 'personalize,' medicines to the delicate and often complex mechanisms possessed by specific patients. Given how significant data-intensive assays are in revealing appropriate intervention targets and strategies for personalizing medicine, AI can play an interesting role in the expansion of personalized medicine at all major phases of clinical development for human beings and the implementation of new personalized health products, from finding appropriate intervention targets to testing them for their value. The authors describe a number of areas where AI can play a significant role in the growth of personalized medicine, and debate that AI's ability to spread personalized medicine will depend judgmentally on the ways of loading, accumulating, retrieving and eventually integrating the data that is created. Authors also share their opinions about the limitations of countless AI techniques, as well as pondering areas for further exploration.

* **Corresponding author Mihir Y. Parmar:** Krishna School of Pharmacy and Research, KPGU, Vadodara, Gujarat, India; E-mail:mihirparmar.ksp@kpgu.ac.in

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

Keywords: AI-based personalized medicine, Artificial Intelligence, Biomedical skills, Clinical data science, Machine learning, Precision medicine.

INTRODUCTION

The delivery of diagnostic, therapeutic, and preventive interventions is predicated on the typical patient one-size-fits-all paradigm in the current healthcare system. Alarmingly, these broad therapeutic approaches do not sufficiently address the medical needs of a sizable percentage of the population, even if they are feasible to implement [1]. For instance, only 40-60% of patients react to treatment when using medication. Significant inter-individual variability is the cause of the varied medication treatment response rates that are currently extensively reported in the medical literature. It is evident that in order to maximize treatment, a more focused approach to medicine is required, which has led to the development of precision. Although the terms “precision medicine” and “personalised medicine” have been used interchangeably, the term “precision medicine” is currently preferred because it is generally agreed that the term “personalised medicine” may be interpreted incorrectly to mean that preventive and treatment plans are specifically tailored to each individual. Given the magnitude of intra- and inter-individual heterogeneity in drug response as well as the epidemiological, pharmacological, and biological perspectives mentioned above, it is reasonable to infer that individualized treatment at the individual level is more inspirational. Medicine may be revolutionized more realistically by identifying and forecasting subgroups that will respond better or worse [2, 3].

Precision medicine, as opposed to the one-size-fits-all approach, seeks to incorporate each patient's distinct characteristics, including biological data gleaned from imaging, laboratory testing, clinical phenotypes, and medical records, in order to provide a customized diagnosis or treatment plan that has a better chance of working. Patients should anticipate better outcomes in the form of earlier, more accurate diagnoses, more effective treatment, and fewer adverse medication responses. Broader benefits should also include increased healthcare savings and increased economic output. Therefore, a more accurate diagnosis and prognosis than those provided by current clinical and epidemiological recommendations are included in precision medicine. The concept of precision medicine arose from the remarkable achievements in identifying discrete subgroups within specific cancer categories by genome sequencing advancements, which were then successfully targeted as molecular cancers. Precision medicine, as opposed to the one-size-fits-all approach, seeks to incorporate each patient's distinct characteristics, including biological data gleaned from imaging, laboratory testing, clinical phenotypes, and medical records, in order to provide a customized diagnosis or treatment plan that has a better chance of working.

Patients should anticipate better outcomes in the form of earlier, more accurate diagnoses, more effective treatment, and fewer adverse medication responses. Broader benefits should also include increased healthcare savings and increased economic output. Therefore, a more accurate diagnosis and prognosis than those provided by current clinical and epidemiological recommendations are included in precision medicine. The concept of precision medicine arose from the remarkable achievements in identifying discrete subgroups within specific cancer categories by genome sequencing advancements, which were then successfully targeted as molecular cancers [4 - 6].

Precision medicine, in contrast to conventional medicine, is extremely data-intensive and necessitates the flow of health data from individual medical records into various research contexts, such as pharmacovigilance, genomic research, clinical trials, and epidemiological studies, and back into a learning healthcare system that the research findings can be applied to practice [7].

Precision medicine necessitates research in order to improve the generalizability of the interventions. This research applies data gathered during clinical care to real-world clinical outcomes. Large-scale clinical and biomedical data collection is being used to support and expedite research, thanks to the growing understanding of precision medicine's potential and value [8].

The authors of a recent National Academy of Medicine report on the state of artificial intelligence (AI) in healthcare today and in the future noted "unprecedented opportunities" to enhance specialist care and the help AI offers in overcoming human limitations like fatigue and inattention as well as the dangers of machine error. Crucially, the paper points out that although these technologies must be used with caution, there is a lot of promise [9].

AI in healthcare is evolving and progressing quickly thanks to the digitization of health-related data and the quick adoption of new technologies. The application of AI in healthcare may be hampered by issues with multimodal data integration, security, federated learning (which necessitates fundamental advancements in fields like privacy, large-scale machine learning, and distributed optimization), model performance, and bias [10].

The effective integration of AI in healthcare requires adherence to three key principles: shared expertise, analytics and insight, and data and security. Ensuring complete openness and confidence in the data and information needed to train AI systems is synonymous with data security. As the collaboration between humans and AI systems grows, we must have faith in the systems' results.

CHAPTER 6

Nanorobots and Nanomedicine in Drug Delivery and Diagnosis

Anupam Mishra[1], **Koushlesh K. Mishra**[1,*], **Sushma Mishra**[2], **Rajeev Mishra**[3] and **Sheetal Mane**[4]

[1] *Shri Rama Krishna College of Pharmacy, Satna (M.P), India*

[2] *D.H. Waidhan, Singrauli (M.P), India*

[3] *APS University, Rewa (M.P), India*

[4] *NMT Gujarati College of Pharmacy Indore, M.P., India*

Abstract: Nanobotics is a developing field of nanotechnology that features a nanoscale measurement and can be anticipated to work at the nuclear, atomic, and cellular levels. Nanobotics offers a new frontier in biomedicine, with the potential to transform diagnostics and therapeutics through its unique ability to manipulate biological systems at a nanoscale level. Nanobots have a carbon-based skeleton and a toolkit that includes components such as a hole containing the medicine, a payload, a capacitor, and a microcamera with a tail having the action of swimming. Nanobots are equipped with special sensors that diagnose target particles and molecules inside the body. These sensors can be used to diagnose and treat different imperative infections like cancer, diabetes, atherosclerosis, kidney stones, *etc.* Nanobots can be used to deliver targeted drugs to target areas of the body that are difficult to reach through traditional drug delivery methods such as blood circulation. Nanobots are either powered by exogenous energy (*e.g.,* magnetic field, light, acoustic field, electric field, *etc.*) or endogenous energy (chemical reactions energy). They have been shown to be capable of encapsulating, transporting, and delivering therapeutic content directly to the site of disease, improving the therapeutic effectiveness and reducing systemic adverse reactions of toxic drugs. This chapter covers the following topics: Nano-based nanobots for diagnostics and disease management, types of nanobots, advantages and limitations, robotic approaches in drug delivery, biomedical applications of nanobots, and their future prospects.

Keywords: Approaches, Diagnosis, Drug delivery, Disease management, Nanobotics, Nanobots.

* **Corresponding author Koushlesh K. Mishra:** Shri Rama Krishna College of Pharmacy, Satna (M.P), India; E-mail: koushleshmishra@gmail.com

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

INTRODUCTION

In the field of pharmaceutical research, drug delivery to target organs, tissues, or cells is always challenging and interesting. Traditional drug delivery methods have not been successful in delivering drugs directly to target organs and achieving maximum therapeutic efficacy with minimal side effects. In traditional drug delivery systems, drug delivery relies on the movement of body fluids as they move through the body. This type of delivery may not treat some diseases, such as stroke or glioblastoma. Existing traditional drug delivery systems deliver drugs directly to the systemic circulation to achieve maximum therapeutic response. Traditional and conventional drug therapy lacks the navigational ability to more precisely deliver drugs to specific target tissues. Delivering drugs to inaccessible tissues in the human body remains a challenge. To achieve targeted delivery of therapeutic agents, drug delivery systems must have autonomous propulsion and controlled navigation. To overcome all these challenges, novel approaches to drug delivery systems are needed [1].

Nanorobotics (Nanobotics) is an emerging field that offers great potential for advanced diagnostics and therapeutics. This area has attracted significant interest among research groups due to its autonomous mobility and ability to perform small-scale, complex tasks. Nanorobots can be a great vision for the future of medicine. Nanorobots (Nanobots) meet all these requirements and serve as a promising strategy to solve all these challenges. An ideal nanorobot should have defined target motion and autonomous drug delivery capabilities [2]. Because nanorobots deliver drugs to specific target locations, they must be delivered safely from within the body without causing toxic effects. Nanorobots released from the body's excretory tract must be biodegradable and stable in the external environment. Traditional drug delivery methods paved the way for tumor-targeted treatment, but they relied on increased permeability and retention or ligand-receptor mediated interaction, resulting in a narrow recognition range (0.5 nm) and low targeting effectiveness (0.7%, median). Alternatively, due to their autonomous mobility and navigation in biological media, micro/nanorobots may operate as new “motile-targeting” drug delivery systems to deliver therapeutic payloads, therefore taking a huge step toward successful and safe cancer therapy [3].

Nanobots typically range in size from 1 to 100 nanometers (nm). Nanorobots are specialized devices intended to carry out a specific duty. Nanobots are miniature molecular nanomachines that can travel independently in biological fluids while hauling payload and penetrating. Nanobots are artificial, intelligent submicron objects that travel across space using self-propulsion or an externally controlled propulsion system. Nanobots are created by combining various components of tiny separate parts or by integrating inorganic components with biological cells or molecules [4]. Nanobots are made of nanomaterials and are programmed to perform a certain task. Nanomaterials are materials with diameters ranging from 1 to 1000 nm. Nanomaterials developed in recent decades have demonstrated potential impacts on medication delivery *via* passive or active targeting mechanisms. Active targeting is mostly based on receptor molecule overexpression, whereas passive targeting is based on the absorption of specific-sized nanomaterials by cancer tissues or lymph nodes. A nanobot is an autonomous, preprogrammed atomic structure [5].

Nanobots are nanoelectromechanical systems with sensing, control, actuation, communication, energy supply, and data transmission properties. The various components of the nanorobot include micro-cameras, electrodes, lasers, ultrasound signal generators, swimming tails, and payloads. Nanobots are nanomachines that connect various interdisciplinary fields of nanotechnology and nanoscience to solve real-time challenges such as targeted drug delivery. Nanobots improve the delivery of drugs and contrast agents to target sites due to their autonomous propulsion and improved navigation through body fluids. Nanorobots are functional molecular devices that can self-assemble, are powered by an external power source, and perform a variety of tasks. These are programmed devices that are inserted through a catheter or injected through a blood vessel and are controlled by an outside surgeon who acts as the on-site surgeon in a variety of complex vascular procedures [6].

Most researchers have chosen intravenous administration as the entry point for nanorobots. Once the nanobot enters the systemic circulation, it is controlled by magnetic fields and field gradients to reach the target site, ultimately activating the nanobot to facilitate drug diffusion across the cell membrane of the target tissue as shown in (Fig. **1**). Nanobots can use endogenous fuels such as glucose, urea, and adenosine-5-triphosphate (ATP) for navigation without the need for external devices or propulsion. When developing nanobots, it is important to develop self-sufficient systems that are non-immunogenic and biocompatible, as well as those that utilize fuel resources that are readily available within the body. Nanorobots behave like swarm devices and can be useful for theranostic applications in biomedicine [7].

CLASSIFICATION OF NANOROBOTS

Nanorobots are generally classified into four categories. Nanorobots are broadly categorized into four main types [8], as depicted in (Fig. 2), which provides a detailed classification [8].

CHAPTER 7

Artificial Intelligence in Herbal Medicine Formulations

Prashant Kumbhar[1], Narendra Kumar Pandey[1], Bimlesh Kumar[1,*] and **Kuldeep Vinchurkar[2]**

[1] *School of Pharmaceutical Sciences, Lovely Professional University, Punjab-144411, Phagwara, India*

[2] *Department of Pharmaceutics and Pharmaceutical Technology, Krishna School of Pharmacy and Research, Drs. Kiran and Pallavi Patel Global Univeristy (KPGU), Varnama, Vadodara, Gujarat-391240, India*

Abstract: One promising way to optimize and improve the development of herbal remedies is to incorporate artificial intelligence (AI) methodology into the field of herbal medicinal formulations. AI methods are being used increasingly to analyze large datasets that include traditional knowledge, pharmacological properties, botanical compounds, and therapeutic effects. These methods include machine learning algorithms, neural networks, and natural language processing. These computational tools make it easier to identify bioactive ingredients, anticipate synergistic interactions, and understand the molecular processes that underlie herbal formulations. Furthermore, the process of drug discovery and development can be streamlined by using AI-driven modeling to quickly screen formulations for safety, bioavailability, and efficacy. The combination of AI and herbal medicine works well together to speed up the search for new therapeutic combinations and facilitate comprehension of the complex interactions between phytochemicals and their biological targets. However, issues like algorithm robustness, ethical considerations, and data quality make more research and validation in this emerging field necessary. However, the combination of AI techniques and herbal medicine formulations has great potential to advance evidence-based and personalized healthcare practices.

Keywords: Artificial intelligence, Computational modeling, Herbal medicine, Interactions, Medicinal formulations, Machine learning, Molecular mechanisms.

INTRODUCTION

In the rapidly growing world of healthcare and pharmaceuticals, the integration of artificial intelligence (AI) has ushered in a new era of innovation and efficiency.

[*] **Corresponding author Bimlesh Kumar:** School of Pharmaceutical Sciences, Lovely Professional University, Punjab-144411, Phagwara, India; E-mail: bimlesh1pharm@gmail.com

One particularly intriguing and promising domain where AI is making significant strides is herbal medicinal formulations [1 - 3]. The core idea of Ayurveda is an understanding of biological system balancing. Ayurveda uses naturally occurring herbs and related techniques to treat illnesses. It is primarily practiced in India and is becoming well-known worldwide. The system of Ayurveda is successful, but it is not widely used. A number of factors have prevented Ayurveda from realizing its full potential, including the lack of emphasis placed on Ayurvedic education and practices, the scant or nonexistent advancements observed, financial constraints, a lack of technical support, and unorganized databases [4 - 6]. Consequently, there is a continuous need to innovate in the field of technology and to efficiently develop knowledge-based systems in order to improve the application of Ayurveda and maximize its advantages [4, 7, 8]. The intersection of traditional herbal medicine with cutting-edge AI technologies holds the potential to revolutionize the way to reach the needs of individuals requiring proper health through healthcare providers. Such approaches play a significant contribution to the speedy delivery of demand to healthcare providers [1, 2]. Assessment of the onset of disease, success of treatment, management of complications, patient care assistance, and research targeted towards rationalized discovery, as well as treatment of the disease, are the five different pillars used in the healthcare systems using AI. These pillars can be a landmark for clinicians, patients, and other healthcare workers [2, 3, 9]. Herbal medicine, with its roots deeply embedded in ancient healing traditions, has long been a source of remedies for various ailments. The vast reservoir of knowledge about the therapeutic properties of herbs, amassed over centuries, is now being harnessed in conjunction with AI to optimize and enhance the formulation of herbal medicines [9]. This synergy between traditional wisdom with modern technology not only preserves the time-honoured principles of herbal medicine but also catapults it into a new era of precision and personalized healthcare [10].

AI has a role in herbal and traditional medicine for the development of formulations. It also extends beyond mere data analysis, synthesis and interpretation of vast datasets, predictive modeling, and the identification of complex patterns within the botanical realm [1 - 3]. Recent reports have provided evidence of the existence of AI where scrutinization of neuroprotective compounds occurs *via* machine learning methods using Xiaoxuming decoction, which affects regulating vascular function and treating stroke recovery [10]. Machine learning algorithms can analyze the chemical composition of herbs, predict their synergism and additive effects, and even suggest novel tentative combinations that may have previously gone unnoticed (Table **1**). These unnoticed combinations can be reconsidered for different targets for the treatment of different diseases. This level of computational analysis enables a more nuanced understanding of the intricate relationships between different herbal components, paving the way for the development of highly targeted and effective formulations [1 - 3].

Table 1. Key features of AI in herbal medicine [7].

Sl. No.	Key Features	AI-driven Results
1	Plant identification	Computerized vision for species recognition
2	Formulation optimization	• Machine learning models for optimizing • Enhancement of efficacy
3	Treatment Strategies	• Creating individualized herbal treatment • Timeline according to the patient clinical state
4	Interaction prediction	Possible potential interaction between herbals and drugs
5	Quality control and authentication	Ensuring authenticity and quality control
6	Efficacy and toxicity	• Identification of models for evaluation • Selection of suitable models • Level of toxicity

Importance of AI in Ayurveda

AI has the power to revolutionize the age-old science of Ayurveda. Possibilities for interdisciplinary research that combines the knowledge bases of AI and Ayurveda can yield ground-breaking results in the diagnosis, treatment, and prevention of illness. Ayurvedic medicine's three core databases—disease, treatment, and human data—are known as the Trisutra. Dosha Prakriti (somatic constitution) and its attributes, Sapta Dhatu (primary body structural components), thirteen Agni types (metabolic/digestive factors), thirteen Srotas (structural or functional body channels), three Mala (body waste products), and Oja (the essence of all seven Dhatu) are included in the first dataset on humans. Medicinal plants with their Rasa (taste), Guna (property/quality/attribute), Virya (potency), and Vipaka (bio-transformed rasa) are included in the second set of Ayurvedic therapeutics. Other procedures include Panchakarma (five internal biocleansing therapies) and Pathyapathya (compatible diet & regimen). The symptoms of the disease come last. Using these three datasets—the Trisutra for AI in Ayurveda—drugs, diet, Dinacharya (daily regimen), and Ritucharya (seasonal regimens) concepts that address chronobiology could be used to diagnose, predict, and prevent disease [1, 4, 11, 12].

Development of a Database for Ayurvedic Reports

Indian medicinal plants and the ways they are used are effective models for treating a variety of common illnesses. The Indian traditional system of medicine, Ayurveda, can be greatly enhanced by classifying Indian medicinal herbs

CHAPTER 8

Role of Artificial Intelligence in Drug Product Design and Optimization of Process Parameters

Pankaj Kumar Pandey[1,*], **Manoj Likhariya**[1], **Juhi Bhadoria**[1], **Kuldeep Vinchurkar**[2] and **Priya Jain**[3]

[1] *Lakshmi Narain College of Pharmacy (RCP), Indore, India*

[2] *Department of Pharmaceutics and Pharmaceutical Technology, Krishna School of Pharmacy and Research, Drs. Kiran and Pallavi Patel Global Univeristy (KPGU), Varnama, Vadodara, Gujarat-391240, India*

[3] *Oxford International College, Gandhi Nagar, Indore, M.P., India*

Abstract: The integration of artificial intelligence (AI) in pharmaceutical research has revolutionized drug product design and the optimization of process parameters, marking a paradigm shift in the traditional drug development paradigm. This abstract explores the multifaceted role of AI in these critical aspects of pharmaceutical manufacturing. The chapter elaborates the significance of AI in revolutionizing processes like drug discovery, formulation optimization, personalized medicine development, predictive analytics, drug design, improved patient outcomes, and many more. In drug product design, AI-driven methodologies have demonstrated unparalleled capabilities in expediting the identification of novel drug candidates and predicting their pharmacokinetic properties. Machine learning algorithms analyze vast datasets, including molecular structures, biological interactions, and clinical trial outcomes, to unravel complex relationships and generate insights that guide rational drug design. This accelerates the discovery process and enhances the efficiency of lead optimization, ultimately reducing the time and costs associated with drug development. Furthermore, AI plays a pivotal role in optimizing process parameters during drug manufacturing. The pharmaceutical industry faces challenges in ensuring the reproducibility, scalability, and cost-effectiveness of production processes. AI algorithms, particularly in combination with process analytical technologies (PAT), enable real-time monitoring and control, ensuring the quality and consistency of drug products. Through iterative learning and adaptive control, AI-driven systems can dynamically optimize manufacturing parameters, minimizing variations and ensuring the robustness of the production process. In conclusion, the incorporation of AI in drug product design and process optimization is transformative, fostering innovation and efficiency in the pharmaceutical industry. As the field continues to evolve, collaborative efforts between computational scientists, chemists, and engineers are

[*] **Corresponding author Pankaj Kumar Pandey:** Lakshmi Narain College of Pharmacy (RCP), Indore, India; E-mail: pankajpandeycop@gmail.com

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

essential to harness the full potential of AI, ultimately advancing drug development and improving patient outcomes.

Keywords: Artificial intelligence, Algorithms, Decision making, Drug product design, Human intelligence, Machine learning, Product development, Regulatory process, Speech recognition, Visual perception.

INTRODUCTION

In early definitions, artificial intelligence (AI) was simply defined as "intelligence exhibited by machines." The intelligence being exhibited was a human-like response to human communication. Today, due to progress in neuroscience, computation, and programming techniques, the focus of AI has shifted to modeling human intelligence, improving computational tools and media, and advancing goal-oriented processing for complex interactive environments. Due to this shift, AI has found application in almost every domain of human experience and now serves a great range of purposes. Its primary value is to quickly, efficiently, and effectively get better results from the purposeful collection and analysis of information. Its secondary value is in the development and application of digital technology to solve problems or render services for commerce, medicine, environmental science, robotics, transportation, communications, and people.

Over the past few years, there has been a dramatic 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. This motivates the use of AI because it can handle large volumes of data with enhanced automation. AI is a technology-based system involving various advanced tools and networks that can mimic human intelligence. At the same time, it does not threaten to replace human physical presence with completely independent decisions for accomplishing specific objectives. Its applications are continuously being extended in the pharmaceutical field, as described in this review. According to the McKinsey Global Institute, the rapid advances in AI-guided automation are likely to completely change the work culture of society.

Drug product design refers to the systematic and creative process of developing a pharmaceutical product that meets the desired therapeutic objectives, as shown in Fig. (**1**). It involves the formulation of the drug substance into a final dosage form, considering various factors such as the physicochemical properties of the drug, desired route of administration, patient compliance, and stability. The goal of drug product design is to ensure the delivery of the right dose of the drug, with the appropriate release profile, in a safe and effective manner [1].

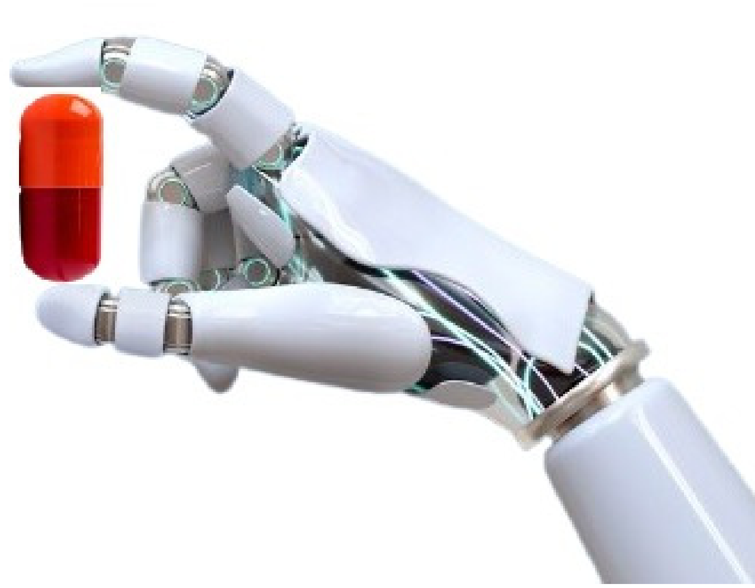

Fig. (1). Drug product design through AI.

The objectives of artificial intelligence in drug product design and optimization of process parameters include:

Assessment of AI Techniques: Evaluate the effectiveness and applicability of various AI techniques (such as machine learning, deep learning, and computational modeling) in drug product design and process optimization.

Optimization of Formulation Parameters: Investigate how AI algorithms can optimize formulation parameters (such as drug-excipient ratios, particle size, and dosage form) to enhance drug efficacy, stability, and patient compliance.

Process Parameter Optimization: Determine the potential of AI-driven approaches in optimizing manufacturing process parameters (including temperature, pressure, and reaction time) to improve product quality, yield, and cost-effectiveness.

Comparison with Traditional Methods: Compare the performance of AI-based optimization strategies with traditional experimental methods in terms of efficiency, accuracy, and scalability.

CHAPTER 9

Regulatory Insights into Artificial Intelligence in Drug Delivery and Medical Devices

Nayany Sharma[1], **Rekha Bisht**[1,*], **Rupali Sontakke**[2] and **Kuldeep Vinchurkar**[3]

[1] *Department of Pharmacology, Indore institute of Pharmacy, Indore, Madhya Pradesh, India*

[2] *Department of Pharmacology, Faculty of Pharmacy, Medicaps University, Indore, Madhya Pradesh, India*

[3] *Department of Pharmaceutics and Pharmaceutical Technology, Krishna School of Pharmacy and Research, Drs. Kiran and Pallavi Patel Global Univeristy (KPGU), Varnama, Vadodara, Gujarat-391240, India*

Abstract: The pharmaceutical industry is grappling with challenges that impede the sustainability of drug development programs, primarily due to escalating research and development costs coupled with diminishing efficiency. This chapter explores the potential of leveraging artificial intelligence (AI), particularly machine learning (ML) and its subset, deep learning (DL), to bring about a transformative impact on the drug development process. ML, characterized by its capacity to learn from data with or without explicit programming, holds promise for addressing the complexities inherent in pharmaceutical research. DL, employing artificial neural networks (ANNs) as a multi-objective simultaneous optimization technique, has demonstrated efficacy in optimizing drug delivery systems. AI has the potential to transform drug discovery, clinical trials, drug delivery, and medical devices, emphasizing alignment with regulatory guidelines. However, challenges such as data quality and model complexity limit its transformative impact on medicine delivery and device development.

This chapter is structured into three parts, each addressing a distinct aspect of AI in the pharmaceutical landscape. The first part provides a foundational introduction to AI in the pharmaceutical industry, elucidating its role in overcoming inherent challenges. The second part delves into the diverse applications of AI-based tools and systems, encompassing drug discovery, various drug delivery systems, and the development of medical devices. Finally, the third part of the chapter sheds light on the regulatory challenges associated with AI-based drug delivery and medical device development, offering insights into the evolving regulatory landscape.

Keywords: Artificial intelligence, Drug delivery, Dosage design, Drug development, Deep learning, Drug discovery, Medical devices, Machine learning, Regulatory.

[*] **Corresponding author Rekha Bisht:** Department of Pharmacology, Indore institute of Pharmacy, Indore, Madhya Pradesh, India; E-mail: rekha_al03@rediffmail.com

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

INTRODUCTION

The pharmaceutical landscape is witnessing a seismic shift with the integration of Artificial Intelligence (AI). This transformative technology is not just a new player in the field, but a game-changer that is redefining the entire drug discovery and delivery process. Traditionally, the journey from the lab to the pharmacy shelf has been a long and winding road, fraught with uncertainties and high failure rates. However, the advent of AI has infused a sense of optimism into this intricate process. ML algorithms, a subset of AI, have proven to be particularly effective [1]. They swiftly sift through vast datasets comprising biological, chemical, and clinical information, thereby accelerating the identification of potential drug candidates. These algorithms can predict molecular interactions, propose new drug compounds, and optimize existing molecules with an unprecedented level of precision and efficiency. Moreover, AI's prowess extends beyond mere data analysis. It has the uncanny ability to uncover hidden patterns within complex biological systems, thereby redefining target identification and validation [2]. Through advanced analytics and predictive modeling, AI algorithms can pinpoint disease mechanisms, identify therapeutic targets, and predict a molecule's efficacy or adverse effects. This significantly reduces the time and resources required for preclinical research. But the story does not end with drug discovery. AI is also enhancing drug delivery mechanisms. The amalgamation of nanotechnology and AI has opened avenues for precise drug targeting, controlled release, and personalized medicine. These synergistic approaches allow for the design of nanocarriers capable of navigating biological barriers and delivering therapeutics directly to the desired site of action, thereby minimizing side effects and optimizing treatment outcomes [3].

While the potential of AI in revolutionizing drug discovery and delivery is undeniable, it also presents formidable regulatory challenges. The dynamic nature of AI algorithms poses unique hurdles in regulatory oversight, particularly in establishing standardized protocols for validating and approving AI-generated findings. The interpretability of AI-generated insights and ensuring their reproducibility present considerable challenges, as regulatory frameworks traditionally rely on transparent and comprehensible data for assessment. Moreover, ethical considerations loom large in the integration of AI into drug development [4]. Concerns regarding data privacy, algorithm bias, and accountability underscore the need for robust ethical guidelines and governance frameworks to safeguard against potential pitfalls. Striking a balance between fostering innovation and upholding stringent safety and efficacy standards remains a focal point in the regulatory discourse surrounding AI in pharmaceuticals [5].

In conclusion, AI represents a monumental shift in the pharmaceutical landscape, heralding a new era of transformative innovations [6]. As we navigate this rapidly evolving landscape, it is imperative to continually re-evaluate our regulatory frameworks to ensure the safe and efficient deployment of AI-powered solutions. This review discusses the potential of AI in drug development and discovery and aims to provide insights into the regulatory framework and challenges as well [7].

PRESENT CHALLENGES IN PHARMACEUTICALS & THE ROLE OF ARTIFICIAL INTELLIGENCE

The pharmaceutical sector is actively engaged in the exploration of small molecules as part of efforts to enhance product quality and customer satisfaction, leveraging the numerous advantages they offer. The chemical synthesis process is straightforward and cost-effective, resulting in the availability of a variety of stable and potent formulations in the pharmacy sector. Despite these advantages, innovative small molecules encounter challenges in the form of competition from generic counterparts and the complex data requirements associated with launching and conducting clinical trials. In response to these challenges, the biomolecular drug industry is experiencing rapid growth as a means to address the limitations posed by the small size of molecular structures and the inadequate dissemination of research and innovations.

Biomolecules, characterized by their larger size and composition of amino acids, nucleotides, or ribonucleotides, such as insulin and adalimumab, present intricate pharmacokinetic aspects. The industry is exploring new technological advancements to overcome these challenges and address related issues. AI holds significant promise in the realms of drug delivery innovation and discovery. However, it is not without limitations, necessitating human intervention or intellectual input to interpret complex results. Algorithmic bias in AI can result in inactive molecules being identified during docking simulations, highlighting the need for human involvement in decision-making and cross-verification to mitigate such issues [8].

Considering these drawbacks, AI has enormous potential for use. It could take a lot of effort to lessen AI's drawbacks and improve its effectiveness and dependability. AI approach incorporates ML or its subcategories, such as natural language processing and DL. Both supervised and unsupervised learning are possible, and the kind of algorithm used is also very important. While unsupervised classification seeks to establish homogenous groupings based on characteristics, supervised learning makes use of known inputs and results.

CHAPTER 10

Artificial Intelligence in Clinical Trials: The Present Scenario and Future Prospects

Praveen Sharma[1], **Leena Pathak**[2], **Rohit Doke**[2,*] and **Sheetal Mane**[3]

[1] *Department of Pharmacology, Indore institute of Pharmacy, Indore, India*

[2] *Department of Pharmacology, Jaihind College of Pharmacy, Pune, Maharashtra, India*

[3] *NMT Gujarati College of Pharmacy Indore, M.P., India*

Abstract: The completion of clinical trials represents a critical phase of 10 to 15 years, with 1.5–2.0 billion USD spent during the drug development cycle. This stage not only consumes significant financial resources but also carries the weight of substantial preclinical development costs. The failure of a clinical trial results in a staggering loss ranging from 800 million to 1.4 billion USD, underscoring the high stakes involved in drug development. Two primary contributors to the elevated trial failure rates are suboptimal patient cohort selection and recruiting methods, along with challenges in effectively monitoring patients throughout trials. Remarkably, only one out of every ten compounds entering a clinical trial successfully makes it on the market. AI holds the promise to revolutionize key aspects of clinical trial design, ultimately leading to a substantial increase in trial success rates. By leveraging AI, improvements can be made in patient cohort selection, refining recruitment techniques, and enhancing real-time monitoring during trials. The integration of AI in these pivotal stages of clinical trials offers a pathway to mitigate the financial risks associated with trial failure, fostering a more efficient and effective drug development process. This book chapter delves into the application of AI techniques, including DL, NLP, DeepQA technology, DRL, HMI, and other advanced methodologies in the context of clinical trials. This abstract provides an overview of how AI interventions can reshape the landscape of clinical trials, offering a glimpse into the present scenario and prospects at the intersection of artificial intelligence and drug development.

Keywords: Artificial Intelligence, AI in healthcare, Clinical trials, Cohort composition, Clinical trial automation, Drug development, Deep learning, Machine learning, Medical imaging, Patient selection, Patient monitoring.

* **Corresponding author Rohit Doke:** Department of Pharmacology, Jaihind College of Pharmacy, Pune, Maharashtra, India; Tel:9834156578; E-mail: rohitdoke2853@gmail.com

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

INTRODUCTION TO ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) is the emulation of human intelligence in machines, designed to mimic human-like thinking, learning, and problem-solving abilities through programming. The goal of AI is to create systems capable of doing activities that previously required human intellect, such as visual perception, speech recognition, decision-making, and language translation [1]. AI comprises a variety of technologies, including machine learning (ML), natural language processing (NLP), *etc.* AI has the potential to revolutionize robotics, and has applications in areas ranging from healthcare to autonomous cars and virtual assistants. AI has the potential to revolutionise businesses by enhancing efficiency, improving accuracy, and decreasing human error. It can rapidly evaluate massive amounts of data and provide predictions or recommendations based on patterns and trends that humans may not perceive. Additionally, AI systems can continuously learn and adapt, allowing them to improve their performance over time [2].

In this segment of the chapter, we have explored the historical evolution of AI, delving into its progression over time. Additionally, we have examined the diverse methods and techniques linked to AI and their significance in the realm of medicine and healthcare.

Evolution of Artificial Intelligence in the Healthcare Sector

The historical development of AI in medicine reflects a dynamic journey marked by challenges, breakthroughs, and collaborations. From the early foundations in the 1950s to the AI winter and the subsequent resurgence in the 21st century, AI's role in medicine has evolved significantly. As we stand on the cusp of a new era, the ongoing advancements in AI continue to redefine the landscape of healthcare, offering unprecedented opportunities for personalized medicine, improved diagnostics, and enhanced patient outcomes. The journey from early conceptualization to the present state underscores the potential for AI to revolutionize [3].

The historical development of AI in health systems can be categorized into distinct time periods, each marked by seminal transformations.

The 1950s to 1970s: Early Foundations and Digitization

The early focus of AI was on developing machines capable of making decisions previously exclusive to human cognition. In the 1960s, the introduction of the first industrial robot arm, animate, and the natural language processing system, Eliza, laid the groundwork for future AI applications. Despite the slow adoption in medicine, this period saw crucial developments in digitizing data, with the creation of PubMed and other tools setting the stage for the growth of AI in biomedicine [4]. ELIZA's foundational work in NLP is mirrored in current AI applications that use NLP to extract relevant information from unstructured data sources. This capability is crucial in clinical trials for identifying eligible participants and generating insights from vast amounts of textual data, thereby speeding up the trial phases and improving data quality.

The 1970s to 2000s: Pioneering Collaborations and AI Winters

The period from the 1970s to the 2000s is often referred to as "AI winter," marked by diminished funding and waning interest in AI. However, collaboration among pioneers persisted, leading to the development of systems like MYCIN, a backward chaining AI system for diagnosing bacterial infections [5]. The foundational work of systems like MYCIN and DXplain is evident in today's advanced AI-driven CDSS. These modern tools assist clinicians in making informed decisions during trials by analyzing vast amounts of patient data and offering evidence-based recommendations, which improve trial outcomes and reduce time-to-market for new therapies. The AI winter did not halt progress entirely, as evidenced by the creation of DXplain, a decision support system was introduced, showcasing AI's potential in generating differential diagnoses based on inputted symptoms. Despite the challenges, this period laid the groundwork for the later resurgence of interest in ML, setting the stage for modern applications of AIM [6].

From 2000 to 2020: Seminal Advancements in AI

The 21st century witnessed significant breakthroughs in AI, with notable advancements from 2000 to 2020. IBM's creation of Watson in 2007, an open-domain question-answer system, demonstrated the potential for AI to compete with humans on a cognitive level [5]. Watson's success on Jeopardy! in 2011 showcased the power of DL and natural language processing. DeepQA technology, employed by Watson, enabled evidence-based clinical decision-making by drawing information from electronic medical records [7]. The use of Watson in identifying RNA-binding proteins altered in amyotrophic lateral sclerosis in 2017 exemplifies the expanding role of AI in biomedical research. The integration of natural language processing into chatbots, such as Siri and Alexa, transforms communication interfaces, enhancing meaningful interactions. DL, a significant advancement in AIM, with the availability of larger datasets and

SUBJECT INDEX

A

Kuldeep Vinchurkar & Sheetal Mane (Eds.)

B

C

D

E

F

H

I

K

L

M

N

O

P

Q

R

S

T

V

W

X

Kuldeep Vinchurkar

Prof. Kuldeep Vinchurkar has more than 11 years of research and teaching experience at both undergraduate and postgraduate levels. He is a leading scientist and academician. He did his post-graduation from Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur (M.H) and completed a Ph.D. from School of Pharmacy, Devi Ahilya Vishwavidyalaya, Indore (M.P.). He has supervised more than 15 M. Pharm research projects. He attended several national and international conferences organized in pharmaceutical field. He has over 35 research and review publications to his credit, 07 national and international patents granted, 05 national books on pharmaceutical sciences. He is a life member of many professional societies as well as a reviewer of many international and national journals. He has received a number of awards, such as "Outstanding Assistant Professor" award in the pharmaceutics category, "Young Scientist Award" in the International conference of IPGA, COFPRI-2023, at university cultural center, etc. His research interest is 3D printing, artificial intelligence (AI), novel drug delivery systems especially gastroretentive drug delivery.

Sheetal Mane

Prof. Sheetal Mane completed Ph.D. from School of Pharmacy, Devi Ahilya Vishwavidyalaya in 2024. She has 09 years of teaching experience and one year of industrial experience in the QC department of Wockhardt LTD, Aurangabad. Her research interest is novel drug delivery systems. She has published and presented 27 research and review papers in reputed journals and conferences. She is a book editor of Springer, Apple CRC Press and scrivener, etc. and has published 12 book chapters in reputed. Presently, she is working as associate professor at Shri Gujarati Samaj College of Pharmacy, Indore (M.P.).