ESSAY COMPETITION - 2023

SHRI B. V. PATEL EDUCATION TRUST
AHMEDABAD, GUJARAT

Shri Bhupendra V. Patel
2-8-1914 7-6-1974

As a visionary and an educationist acclaimed as the father of Drugs Legislation in India, Shri Bhupendra V. Patel made everlasting contributions to the field of pharmacy at national and international level. He was the first Director of the Drugs Control Administration of Gujarat State. He served as the Vice President of the Commonwealth Pharmaceutical Association. Shri B. V. Patel's life and career continue to be a source of inspiration to the pharmacy fraternity.

SHRI B. V. PATEL EDUCATION TRUST

(TRUST REG. NO. E-2571)

AHMEDABAD, GUJARAT

ESSAY COMPETITION - 2023

ON

"INCREASING ROLE AND IMPORTANCE OF ADVANCED TECHNOLOGIES LIKE ARTIFICIAL INTELLIGENCE, BLOCK CHAIN TECHNOLOGY, 3-D PRINTING IN DRUGS AND PHARMACEUTICAL INDUSTRIES"

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Subject

"INCREASING ROLE AND IMPORTANCE OF ADVANCED TECHNOLOGIES LIKE ARTIFICIAL INTELLIGENCE, BLOCK CHAIN TECHNOLOGY, 3-D PRINTING IN DRUGS AND PHARMACEUTICAL INDUSTRIES"

Number of Entries

20 from all over India

PANEL OF JUDGES

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WINNERS

GOLD MEDAL
DR. PULAK MAJUMDER
Associate Professor,
Dept. of Pharmacognosy, Sri Adichunchanagiri College of Pharmacy
BG Nagar P.O., Nagamangala Taluk, Mandya Dist., Karnataka, 571448

SILVER MEDAL
MS. DHWANI RANA
Ph.D. Research Scholar
National Institute of Pharmaceutical Education and
Research-Ahmedabad (NIPER-A).

The winner of the essay competition- 2023 along with the medals will be awarded a certificate and cash prize of Rs. 31000/- to rank first and Rs. 21000/- to rank second.

In addition, Ten Participants- Dr. Piyush Mehta – Cipla R&D Center, Mumbai, Dr. Deepika Somani - JIP Medical Education and Research, Puducherry, Mr. Devarsh Sutaria - Nirma University, Ahmedabad, Dr. Lakshmi P. Nori - Shri Vishnu College of Pharmacy Bhimavaram, Dr. Meenakshi Patel - Parul University, Vadodara, Ms.Nandita Chawla- LJ Institute of Pharmacy, Ahmedabad, Dr. Sadhana Shahi -Govt. College of Pharmacy, Aurangabad, Ms. Aparajita Patil – Oriental College of Pharmacy, Sanpada, Dr. Anshu Srivastava – Institute of Pharmacy, Nirma University, Ahmedabad, Ms. Abhilasha Sharma - Gujarat University, Ahmedabad will be awarded Certificate of Participation.

FIRST PRIZE(GOLD MEDAL) - 2023

DR. PULAK MAJUMDER

Dr. Pulak Majumder is currently working as an Associate Professor at Faculty of Pharmacy, Sri Adichunchanagiri College of Pharmacy, Adichunchanagiri University since 2019 till date. He has teaching and research experience in the field of Phytopharma-ceuticals and herbal product developments. His accomplishments are undersign-

- ► Research/ Review publication: 36
- ► Patent- 02
- ► Book publication:04
- ► Book chapters: 03
- ► Honors and awards:

- 'Best scholar award' from Operant Pharmacy Federation and Pharma Talk Research Foundation in the year 2019.
- 'Young scientist award' in 2020 form VDGOOD (Technology Factory).
- 'InSc Research Excellence Award' in the year 2020 from Institution of scholars, Bangalore.
- SAS Fellow Member (FSASS) from Scholars Academic and Scientific Society, Assam in 2021.

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SECOND PRIZE(SILVER MEDAL) - 2023

DHWANI RANA

Dhwani Rana is currently pursuing her Ph.D. from NIPER, Ahmedabad, She completed her M.Pharm from NIPER Ahmedabad in the year 2021 and B.Pharm from L.M. College of Pharmacy in the year 2019. Her core competency include: Formulation Development- Systematic product development employing Quality by Design driven approach for quality risk management. Excipient compatibility study, pre-formulation studies, reverse engineering. Skilled in tissue culture techniques and animal handling. Currently she is exploring novel compositions for the development of ophthalmic inserts using hot melt extrusion (HME) and CaliCut technology. She has worked on peptide delivery and developed Teriparatide loaded nanoliposomes employing QbD approach for the treatment of osteoporosis followed by in-vitro characterization of the developed formulation. Formulated an intranasal delivery system of almotriptan malate using the Quality-by-Design (QbD) approach followed by its pharmacokinetic evaluation for the treatment of migraine. Fabricated an implantable electrospun nanofiber composite for ocular delivery of levofloxacin using unique polymeric blend. Also, developed polymeric ocular of dexamethasone employing the same technique and Developed microemulsion of dexamethasone and amorphous solid dispersion of budesonide. She has 9 Research papers, 7 book chapters and 13 Review articles to her credit. She is also recipient of Khorana Scholar Award in March 2020 by Department of Biotechnology (DBT), Govt. of India, WINStep Forward, and the Indo-U.S. Science and Technology Forum (IUSSTF). She was selected to work in the lab of Dr. Abu Serajuddin at St. John's University, NY, United States, focusing on solubility enhancement techniques aimed at Hot Melt Extrusion and Received Dr. B. K. Bacchawat Award for Third Prize for Pre-Clinical Poster Presentation at the 13th International Annual Conference of SAC-ACCP.

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FIRST PRIZE(GOLD MEDAL) - 2023

"INCREASING ROLE AND IMPORTANCE OF ADVANCED TECHNOLOGIES LIKE ARTIFICIAL INTELLIGENCE, BLOCK CHAIN TECHNOLOGY, 3-D PRINTING IN DRUGS AND PHARMACEUTICAL INDUSTRIES"

SYNOPSIS

By utilizing cutting-edge technologies like AI, 3D printing, and blockchain, the pharmaceutical industry is discovering new approaches to medication development, enabling quicker and more accurate data analysis, and eventually improving patient outcomes. The adoption of more effective, automated procedures that include data-driven choices and make use of predictive analytics tools is increasing in the pharma and biotech industries. Artificial intelligence and machine learning will be included into this kind of sophisticated data analytics in the future. The greatest part is that since AI systems are created to provide better results as they continuously learn from fresh data and experience, they may be a potent tool in the research and development branch of the pharmaceutical sector. Traditional manufacturing procedures are already being redefined by 3D printing, often known as additive manufacturing. Technology will probably become more accessible and adaptable as it develops, allowing for decentralized manufacturing, individualized designs, and decreased waste. Through the development of individualized medical implants and prostheses, this democratization of manufacturing has the potential to upend supply chains, spur local production, and potentially change healthcare. In the field of pharmaceuticals, there are six primary categories of 3D printing techniques being investigated. Each method has its own set of technical specifications and yields therapeutic solutions from orally disintegrating and quickly evaporating drugs to delayed and sustained release preparations. Contrarily, blockchain is altering the way we see trust and transparency in business interactions. Beyond bitcoin, its

decentralized and tamper-resistant nature has consequences. Only a few industries, like supply chains, identity verification, and digital rights management, may profit from the safe and unchangeable record of a blockchain.

Fusion of these technologies may provide even more amazing futuristic results. Development of AI, 3D printing, and blockchain technology promises to usher in a time when the possibilities are endless.

"Increasing role and importance of advanced technologies like artificial intelligence, blockchain technology, 3-D printing in drugs and pharmaceutical industries".

Today everything in life has been impacted by technology. Therefore, it should come as no surprise that technology has significantly advanced the worldwide pharmaceutical sector too. Incorporating technology into the pharmacy sector has made it easier for pharma professionals and also improved patient care services. Nobel Peace Prize recipient Sri Kailash Satyarthi, once rightly stated that "Technology can bring about a tremendous transformation in the lives of people and bridge the gap between the haves and have-nots".When we think about emerging medical technology we certainly start visualizing robotic surgeons, artificial intelligence (AI) computers, and 3D-printed organs and so on. However, the ambitious and underutilized techniques now used in drug discovery and development may prove to be as intriguing.

In order to address the needs of patients everywhere, the pharmaceutical sector is a dynamic and complicated sector of the economy. The way pharmaceuticals are discovered, created, and given to patients has changed as a result of technology's increasing importance in this sector in recent years. In addition to showcasing some of the emerging trends and how they are being used in the business to improve lives all over the world, it examines the significance of technology in the pharmaceutical industry.

1. The Growing Need for Technology in Pharmaceuticals

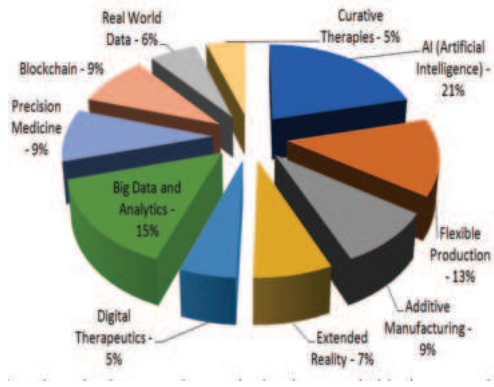
In recent years, the pharmaceutical industry has undergone substantial upheaval, with the advent of new technologies playing a critical role in determining its future. According to a Grand View Research analysis 2022, the size of the worldwide market for

pharmaceutical technology is anticipated to reach $147.5 billion by 2028. The expansion of digital platforms and technology in drug research and discovery is responsible for this rise.

The industry has acknowledged the expanding need for technology in medication discovery, development, and delivery as patient and healthcare provider needs continue to change. By utilizing cutting-edge technologies like AI, 3D printing, and blockchain, the industry is discovering new approaches to medication development, enabling quicker and more accurate data analysis, and eventually improving patient outcomes. Currently there are the top 10 trends and breakthroughs in the pharmaceutical industry, according to a recent analysis by StartUs Insights 2023, where it indicates nearly 40% of breakthroughts are in three areas i.e., AI, 3D printing, and blockchain technology.

According to a Global Data poll conducted this year, the pharmaceutical sector expects drug research to be the area most affected by the use of smart technology. Pharmaceutical Technology examines some of the technology advancements and methods that could revolutionize drug research as the year comes to a conclusion. Despite the pharmaceutical industry's delayed adoption of technical advancements, the start of the pandemic has significantly altered the situation. Due to the difficulties and interruptions brought on by the coronavirus pandemic, pharmaceutical businesses are increasingly adopting the most recent technology to develop individualized medicine, speed up R&D efforts, and improve the user experience.

Here is a look at some of the technologies that are transforming the pharmaceutical sector as technology advancements continue to support industry development.



2. Artificial Intelligence (AI) in the Pharma Industry: A Trending Role

In the past several years, the application of artificial intelligence (AI) in the pharmaceutical and biomedical sectors has advanced from science fiction to reality. The adoption of more effective, automated procedures that include data-driven choices and make use of predictive analytics tools is increasing in the pharma and biotech industries. Artificial intelligence and machine learning will be included into this kind of sophisticated data analytics in the future.

Grand View Research, 2022 estimated that the market size of AI in healthcare may reach of $31.3 billion dollars in 2025. Production companies are shifting towards AI to streamline and automation process as well as post-launch and marketing strategies. Many sectors, including medicine and biotech, are already being transformed by the use of AI for data mining and analytics. It is being use for a variety of clinical applications, i.e., novel drug research, automatic production process and surgical robotics etc.

2.1 Artificial intelligence (AI): Types

Nowadays, **human-made data science algorithms** constitute the foundation of the majority of AI solutions. Multivariate data analytics supplemented by historical experience data are used in this sort of AI.

Machine learning, type of AI which is known as neural networks try to make copy of human brain functions may have the advantage of prompt and accurate judgments, is another level of AI. Machine learning makes use of data-driven techniques to let software programs anticipate outcomes extremely accurately without the requirement of explicit programming.

Another type is next level of AI i.e., **Deep learning,** the, offers a lot of potential for diagnostic applications because it is likewise based on neural networks but incorporates several layers of computations and integrated signals.

2.2 AI's significance in pharmaceuticals

Artificial intelligence (AI) may be used in practically all facets of the pharmaceutical sector, from production and marketing to medication research and development. Pharma industries make all business activities productive, affordable, and hassle-free by utilizing and integrating AI technology into the core workflows. The greatest part is that AI systems are created to provide better results as they continuously learn from fresh data and experience, it can be a potent device in the R & D branch of the pharmaceutical sector.

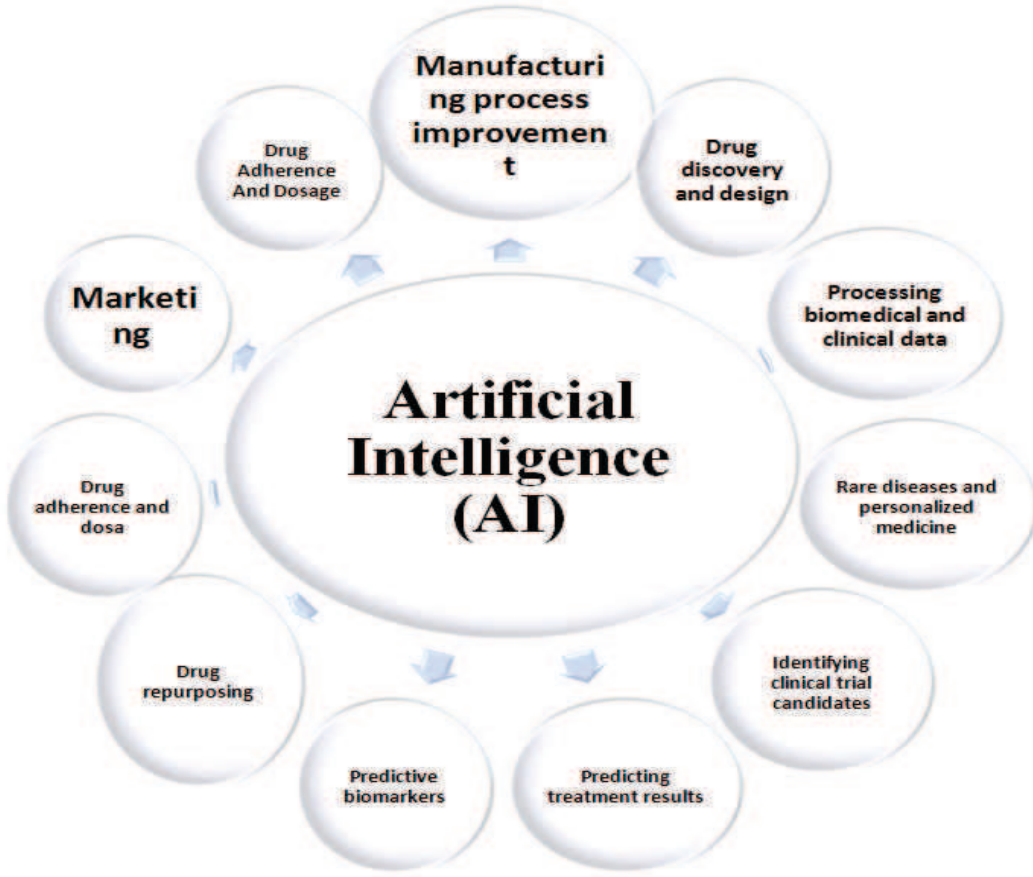


Fig.1 Intelligence in the pharmaceutical sector

Here are a few of the most noteworthy uses of artificial intelligence in the pharmaceutical sector. It includes-

2.2.1 Research & Development

The drug development process is being streamlined by pharma sector around the world using cutting-edge Machine Learning and AI. As a result of their ability to recognize complex patterns in vast datasets, these intelligent technologies may be utilized to address problems relating to sophisticated biological networks.

2.2.2 Developing Drugs

AI is capable of developing and detecting novel compounds and validating target-based medications. Currently 13.8% of medications pass clinical trials successfully (MIT research). Additionally, a pharmaceutical firm must spend anywhere from US$ 161 million to US$ 2 billion for a medicine to successfully complete a clinical study and receive FDA clearance. These are the two key factors driving the growing use of AI by the pharmaceutical industry to lower operating costs, increase medicine and therapy affordability, and increase the success rates of new treatments.

2.2.3 Quick diagnosis

Large amounts of patient healthcare data may be collected, processed, and analyzed by doctors using cutting-edge machine-learning algorithms. These records are accessible to doctors as needed to help them comprehend how a patient's health may be impacted by a particular genetic characteristic or how a certain medication may be used to treat a problem. Currently FDA has approved the sale of the GI Genius medical gadget, which is based on machine learning and

employs an AI algorithm.

2.2.4 Health Promotion

The pharmaceutical industry may employ AI to create treatments for both common diseases like Parkinson's and Alzheimer's as well as unusual disorders. Since the return on investment (ROI) is so poor relative to the time and money required to create pharmaceuticals to treat uncommon diseases, pharmaceutical firms often do not devote their time and resources to developing cures for rare diseases.

2.2.5 Forecasting epidemics

Many drug manufacturers and healthcare providers now utilize AI and ML to track and predict epidemic outbreaks throughout the world. These technologies draw information from various online sources, analyze how different geological, environmental, and biological factors affect the health of the population in various regions, and attempt to draw connections between these factors and previous epidemic outbreaks. Such AI/ML models are especially beneficial for developing nations without the financial and medical infrastructure needed to handle an epidemic breakout. The ML-based Malaria Outbreak Prediction Model, which serves as a warning tool for potential malaria outbreaks in recent times.

2.2.6 Distance Monitoring

In the pharmaceutical and healthcare industries, remote monitoring is a breakthrough. A large number of pharmaceutical companies have already created wearables that use AI algorithms to remotely monitor patients with serious illnesses. For instance, Tencent Holdings and Medopad developed an AI system that can remotely monitor patients

with Parkinson's disease and cut the time needed to do a motor function evaluation from 30 minutes to 3 minutes. It is feasible to see the opening and shutting actions of a patient's hands from a distance by fusing this AI technology with Smartphone apps. The AI will notify the doctor and schedule a check-up in the event that the problems worsen and necessitate an update in therapy.

2.2.7 Fabrication

AI used in the manufacturing process by the pharmaceutical industry to increase productivity, enhance efficiency, and hasten the creation of life-saving medications. All parts of the manufacturing process, including quality control, predictive maintenance, waste reduction, design optimization and process automation, may be managed and improved with AI. AI can take the role of labour-intensive conventional production methods, enabling pharmaceutical companies to get new pharmaceuticals to the market considerably more quickly and inexpensively.

2.2.8 Marketing or advertising

AI is a useful tool in pharma marketing given that the pharmaceutical industry is a sales-driven sector. With AI, pharmaceutical businesses may investigate and create distinctive marketing plans that guarantee strong sales and brand recognition.

AI may assist in mapping the customer journey, giving businesses the ability to determine which marketing strategy generated leads for them (lead conversion) and eventually convinced those leads to make a purchase from them. Pharma businesses are able to concentrate more on the marketing techniques that produce the greatest conversions and raise profits in this way. AI systems may evaluate and compare the outcomes of previous marketing initiatives to determine which ones continued to be the most successful. This saves time and money

while also enabling businesses to design their current marketing strategies properly. AI systems can even anticipate with accuracy the success or failure rate of marketing efforts, in addition.

2.2.9 Medication Compliance and Dosage

Artificial intelligence (AI) is being used in pharmacy at a rate that has never been seen before. AI is increasingly being utilized in the pharmaceutical industry to determine the proper dosages of medications to be taken in order to protect drug users. In addition to assisting with patient monitoring throughout clinical trials, it also recommends the proper dose at regular intervals.

One of the main causes of the rising need for accuracy in this business is artificial intelligence, which has sped up the automation of procedures in the pharmaceutical industry. The potential applications of AI in the pharmaceutical industry are immeasurable and guarantee compliance and efficiency. Additionally, AI in the pharmaceutical industry has opened up a number of possible AI opportunities for workers, many of which have excellent wages and perks.

2.3 Current AI practices in Pharma sector

Using this real-time data, let us better comprehend the effect of AI on the pharmaceuticals and healthcare sectors.

1. Pharmaceutical giant AstraZeneca has used AI and machine learning (ML to accelerate innovation in the pharmaceutical business by expediting the discovery of prospective therapeutic targets and improving the development process.

2. DevisionX has created a computer vision system using artificial intelligence (AI) that can identify faulty medications on conveyor belts.

This technology greatly enhances medication manufacturing procedures by assuring high-quality output.

3. Google with Emory University has used artificial intelligence as a proactive strategy enables healthcare professionals to more effectively distribute resources, which ultimately improves patient care.

4. **Alto Neuroscience** leverages AI-enabled platform that measures brain biomarkers, such as electroencephalogram (EEG) activity and behavioral patterns, wearable data, genetics, and other characteristics, to support the creation of tailored drugs for mental health.

5. **GenAI copilot** for predictive analytics has been unveiled by Clarify Health, a California-based corporate analytics startup. It is built on the startup's Clarify Atlas platform, which maps more than 300 million patient experiences and uses artificial intelligence to generate more than 18 billion predictions and reveal insights quickly.

6. The STFC Hartree Centre, IBM, and Japan's REPROCELL have joined together to create Pharmacology-AI, a platform that makes it easier and faster to analyze large amounts of data from drug development research.

2.4 The way forward with artificial intelligence

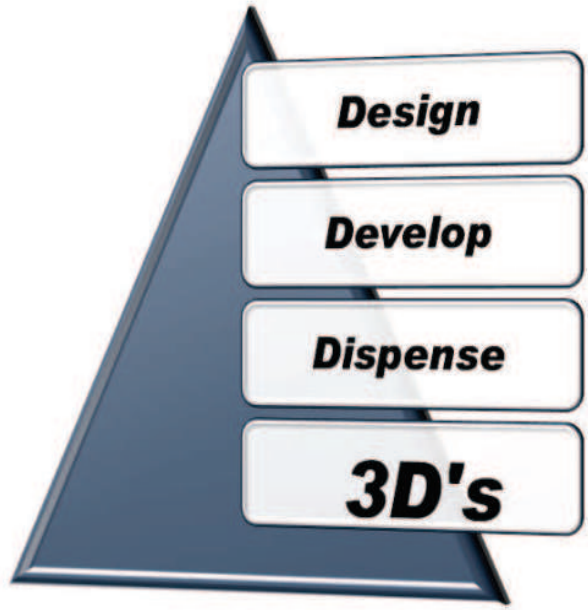
According to researchers, by 2025, nearly half of all healthcare institutions worldwide will have integrated this technology into their daily operations. The use of artificial intelligence in pharmacy is expanding in this way. It is anticipated that drug research companies would increase their investments in this technology in order to identify novel treatments for cancer and chronic disorders. Diabetes, cancer, and chronic kidney illnesses are a few of the key chronic diseases that artificial intelligence is predicted to help treat.

The use of AI in the pharmaceutical sector appears to be quite promising, to sum up. It will lead to the democratization of these cutting-edge technologies, making it more accessible for small and medium-sized pharmaceutical enterprises as more and more pharma companies use AI and ML technology.

3. The role of 3D printing for medications in pharmaceuticals

The pharmaceutical manufacturing might be completely transformed by 3D printing, yet few 3D-printed drugs have received regulatory approval since the first one in 2015 (Spritam® - a levetiracetam tablet). Despite the undeniable importance of generic drugs, there has been a significant movement towards personalized and customized care, which has been aided by the advancement of omics technology in the medical field. The industry has grown year over year, with sales of 3D-printed pharmaceuticals estimated to reach $175.19 million in 2020 and $285.17 million by 2025.

Three-dimensional (3D) printing, also known as additive manufacturing, is a technique that might meet the need for personalized medicines. It employs a computerized model to direct the layer-by-layer building of a 3D object. The pharmaceutical industry could be drastically disrupted by 3D printing technologies because they could enable the on-demand production of products with customized dosages, drug combinations, geometries, and release



characteristics that are not possible with current conventional manufacturing techniques like tableting and encapsulation.

Today, a variety of printing processes are referred to together as "3D printing." The '3 Ds of 3D printing' are a set of guidelines that all 3D printing technologies generally adhere to in order to produce prints, and they open the door to the eventual application of this technology in healthcare settings.

Design: To create the formulation by using digital computer-aided design software. For instance, printlet geometry (shape and size) can be tailored to the pre-clinical or clinical needs.

Develop: Printlets are created by loading the chosen 3D printer with the necessary "ink" cartridge, which is a mixture of medicine and excipients. In general, based on the printer type, drug properties, and intended results, the most suitable printing settings (such as resolution, temperature, and printing time) are chosen;

Dispense: It can "dispense" the printed formulas when the 3D printer has finished automatically layer-by-layer preparing them.

3D printing offers flexibility in the design of complex 3D structures within drugs, the adjustment of drug doses and combinations, and rapid manufacturing and prototyping for personalize pharmaceuticals, and a significant breakthrough in drug manufacturing.

3.1 Technologies used in the 3D printing of medicines

3D printing is an "additive manufacturing" technology, as opposed to the traditional manufacturing methods of "subtractive manufacturing," in which a model is created using computer-aided design software, sliced, and transferred to a printer, where the 3D product is then constructed layer by layer using the principle of additive manufacturing.

Ibuprofen hydrogels, progesterone with pseudoephedrine drug delivery systems, as well as polypills like guaifenesin and the multi-active combination of Nifedipine, Captopril, and Glipizide, are just a few examples of the various healthcare items that can now be found on the market that were 3D printed.

In the field of pharmaceuticals, there are six primary categories of 3D printing techniques being investigated. Each method has its own set of technical specifications and yields individualized therapeutic solutions with a range of features, from orally disintegrating and quickly evaporating drugs to delayed and sustained release preparations.

Figure 2 gives a schematic of the technologies, information on each one, and examples of the different therapeutic products that may be created with limitations.

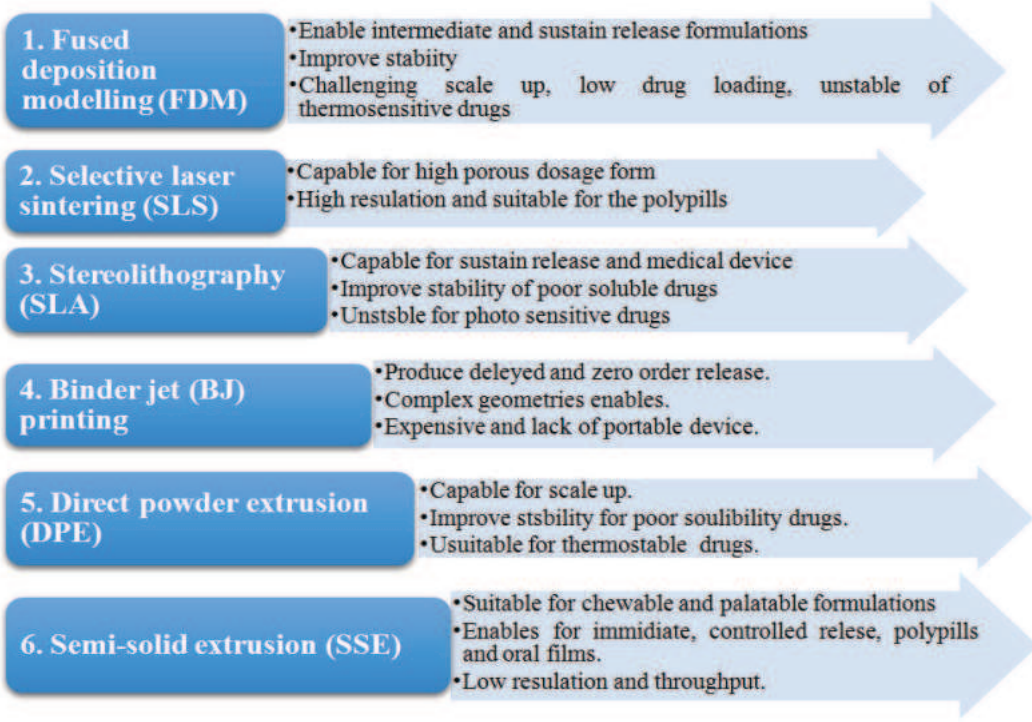


Fig. 2 Six primary categories of 3D printing techniques

3.2 Impact of 3D printing on the pharmaceutical sector

The pharmaceutical sector may profit greatly from 3D printing technology, particularly in the early stages of medication research. 3D printing is utilizing as a quick prototyping method to assess one-off or small batches of various medication product interactions during pre-clinical and clinical formulation development. The evaluation of the effects of various formulation compositions on crucial quality parameters (such as medication performance in vitro and in vivo models) sped considerably. As compared to arduous conventional manufacturing techniques, 3D printing may make it possible to identify process and formulation factors early, which would speed up the entrance into first-in-human (FIH) clinical trials and cut down on the time and expense of development.

For mass-customized or personalized medications, 3D printing employed as an alternative production technique in the pharmaceutical sector. Economically speaking, it is probable that traditional manufacturing techniques for high-volume, low-value medications will continue to be effective in centralized facilities.

3D printing can be useful for formulations that need to be personalized. In the healthcare sector, 3D printing is already being used to produce individualized hearing aids at scale (roughly 1,000 devices per day), each of which is customized in shape and size to the patient's ear canal. Formulations could be mass customized to patient requirements using this technology at regional hubs.

Pharmacies, clinics, and even patients' homes may all be decentralized venues where pharmaceutical corporations employ 3D printing to provide medications on demand. Additionally, this would make it possible for pharmaceuticals to eliminate the need for energy-intensive storage conditions.

3.3 A strategy for the integration of 3D printing in pharmacy

The applications of 3D printing technology to the production of

pharmaceuticals and patient care are numerous. Before widespread integration in the pharmaceutical industry is possible, there are still a number of obstacles to be overcome, such as regulatory requirements, building a stronger body of evidence to support safety and efficacy, and developing dosage forms and 3D printers that are suitable for use in the industry and are well-liked by patients, clinicians, and pharmacists. The development of pharmaceutical 3D printers, which allow the fabrication of printlets that are safe and effective for pharmaceutical usage, has recently been a joint effort between biotech businesses and regulatory organizations.

3.4 Current applications of 3D printing in real time

A multi-nozzle GMP 3D printer for drugs created was created by FabRx in collaboration with regulatory organizations, such as the MHRA, and hospital end-users for design a system suited for this usage.

The ZipDose technology from Aprecia Pharmaceutical, a scaled-up binder jet printing method, for enables the mass production of extremely porous and quickly dissolving medicinal products including levetiracetam for the treatment of epilepsy.

A scaled-up melt extrusion method that Triastek has unveiled enables the manufacturing of distinctive medicinal formulations for clinical trials.

Other manufactures like DiHeSys, Vitae Industries, and Craft Health are all striving to produce GMP-compliant pharmaceutical printers.

Presently, only a few studies have been conducted in real-world' clinical settings with patients to assess the acceptability of 3D-printed formulations and pharmacists as the end-users of the technology. It is essential to adopt a multidisciplinary approach to 3D printing research, and all key players—including big pharma, physicians, patients, and pharmacists—need to get together to debate the future of this technology in the industry. It is also necessary for funding organizations supporting research to increase their contributions.

3. Blockchain technology in Pharma

Currently, there are many new technologies as we discussed being promoted, but the blockchain has been gaining popularity as a decentralized ledger system that can be applied in a number of contexts. Blockchain has endured from its conception in the 1920s as a potentially disruptive breakthrough that will change how people collaborate, automate payments, monitor markets, and record transactions. The adoption of blockchain technology has the potential to be extremely beneficial in removing the requirement for a central authority figure to supervise and verify agreements and transactions between several parties. Every mining node hashes and verifies each transaction on the blockchain using cryptography. It generates time-stamped documents that are safe, accessible, and unchangeable. All parties may access them.

4.1 Development of Blockchain Technology

The main components of blockchain technology are broken down into three groups. Each of them performs in a unique way.

4.1.1 Distributed Network: Nodes for network users make up the architecture of a decentralized P2P network. Each participant can store an exact copy of the Blockchain and verify and validate digital transactions for the network.

4.1.2 Electronic Transaction: Any digital asset that is stored on a blockchain may be subject to a digital transaction. Each transaction will result in the creation of a "block". Each block contains a cryptographic hash that is used to add the transactions in reverse chronological order.

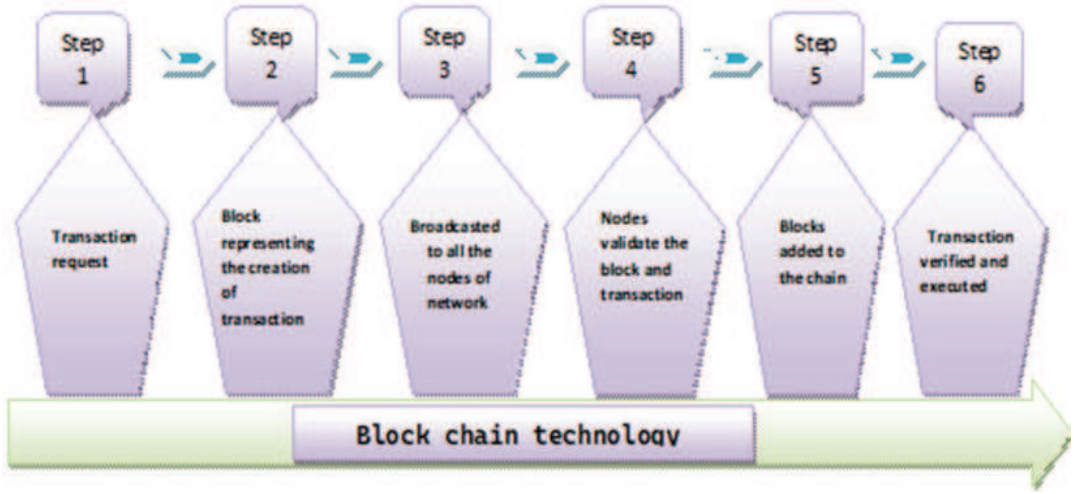
4.1.3 Joint Ledger: The network participants keep track of all recent digital transactions in a common ledger. The offered transaction is examined using algorithms, and if it has received the approval of a sizable number of partners, it is added to the shared ledger.

The three components that make up the blockchain technology work

process were previously mentioned. Let's move on to the main advantages of blockchain in healthcare now that you are familiar with it and how it operates.

4.2 'Self-regulation' of the pharmaceutical industry through block chain-enabled trust

Every nation is presently addressing the threat posed by the sale of counterfeit medications, which is a worldwide issue. It is a growing global issue that has a significant effect on lower middle-income and lower income countries. According to current estimates from the WHO, one in ten of the medications circulating in low- and middle-income nations are either subpar or fake. According to the National Drug Survey 2014–2016, carried out by the National Institute of Biologics, Ministry of Health & Family Welfare, counterfeit or substandard medications make up around 3% of all pharmaceuticals in India. It was realized that there is an urgent need for greater visibility and traceability into the origin of medicines and how they have been handled throughout their journey in the supply chain due to the growing threat of fake drugs entering the supply chain, especially getting into the hands of customers.



4.3 Current practices and constraints

When the products are transferred between the various stages and layers of the intricate supply chain (i.e. wholesalers, distributors, or sub-distributors), there is a risk of the entry of fake drugs. This finding was supported by research and interviews conducted during the initiative's early stages. Drugs are susceptible to theft, adulteration, and replacement at every stage of transit from the factory to the patient. Such misconduct results in financial loss for the drug manufacturers and, more significantly, poses a serious danger to patient safety. On the basis of the GS1 standards, a new system for drug tracking and traceability dubbed Drug Authentication and Verification Application (DAVA) has been developed and put into use by the National Informatics Centre. The method relies on the usage of Global Trade Item Numbers (GTINs) and serial numbers supplied by manufacturers to identify the various hierarchy levels for product packaging. By giving real-time visibility of medications manufactured and exported from India, the goal is to enhance India's reputation as a global leader in the development of safe pharmaceutical goods. A total of 2000 manufacturers will take part in the DAVA system when it is fully implemented, with the involvement of big and medium-sized businesses coming first, then small-scale enterprises. Barcode labeling and tagging will be required at the secondary and tertiary levels, although barcoding at the primary level will be optional.

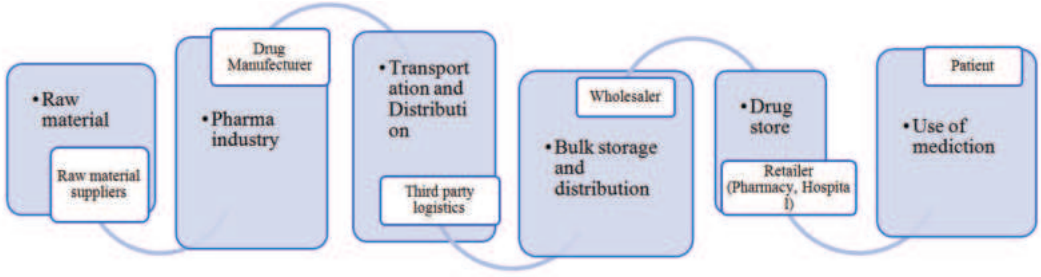
However, it was discovered that DAVA may not have all of the capabilities that blockchain can, even if it does give information on items at the manufacturer level that can be validated by other stakeholders. For instance, it does not guarantee that every stakeholder can see each transaction, which is crucial in a situation with many stakeholders, locations, and products. Additionally, it is unable to monitor product compliance with temperature requirements and follow it along the supply chain. These are now possible because to developing technologies like the Internet of Things (IoT) and blockchain. Each transaction was pushed automatically by internal systems as the pharmaceutical medication went through the

supply chain, recorded in the ledger, and time-stamped using the ledger to guarantee product security and safety. A significant amount of linked data may be presented to the stakeholders without endangering the data security thanks to decentralization, encryption techniques, and immutable record keeping. Even the manufacturing inputs, such as excipients and active pharmaceutical components, were recorded and connected to the finished pharmaceutical goods. Additionally, the blockchain recorded crucial information from IoT sensors attached to the parcels, such as location and temperature, making the journey transparent to all parties and reducing the chance of record manipulation. Through the use of IoT sensors and a mobile application, the project's scope permitted track and trace beyond conventional techniques by enabling users to confirm that the requirements for the transit of medications had not been violated. The global standards organization, GS1, provided specially designed bar codes to facilitate tracking.

4.4 Consensus on the advantages of blockchain technology

Blockchain technology has been discovered to have the potential to increase transactional dependability, efficiency, and transparency in the highly regulated pharmaceutical business. Drug producers and other supply chain counterpart's uses blockchain to access on-time data and improved visibility across the entire supply chain. These key advantages are noted below:

- Streamline the visibility of drug or medicine movement for each value chain stage and participant which enhanced traceability makes



it easier to optimize drug flow and implement an effective inventory management system, which significantly improves stock planning.

- Each point of ownership allows for the tracking of medicine shipments across the supply chain and additionally, it is feasible to identify the participants in the supply chain.

- It can help to identify the last stakeholder the product passed through in the event that an issue occurs during the delivery of pharmaceuticals or treatments.

- It also enables the effective distribution of "batch reminders" to maintain patient health and safety, as well as to find the precise place of medications at single transaction.

- Pharma industries will be able to lessen their reliance on middlemen, assure stock movement transparency, maintain quality control, and enhance the industry's reputation overall with the use of blockchain technology when it is implemented in the supply chain.

- A shared public infrastructure that is constructed on top of a blockchain system can be enabled with the help of the government. Several government health-related programs might benefit immensely from this as well.

5. Conclusion and future prospective

To sum up, the interconnected trajectories of AI, 3D printing, and blockchain technology show enormous promise for influencing the future of several sectors and facets of our life. The way we create, manufacture, do business, and interact is about to undergo a change thanks to these disruptive technologies. With its capacity to handle enormous volumes of data, identify trends, and make predictions, artificial intelligence will continue to push automation and efficiency across sectors. AI has the ability to improve decision-making, boost efficiency, and open up new doors for innovation across a wide range of industries, including healthcare, finance, transportation, and entertainment.

Traditional manufacturing procedures are already being redefined by 3D printing, often known as additive manufacturing. Technology will probably become more accessible and adaptable as it develops, allowing for decentralized manufacturing, individualized designs, and decreased waste. Through the development of individualized medical implants and prostheses, this democratization of manufacturing has the potential to upend supply chains, spur local production, and potentially change healthcare.

Contrarily, blockchain is altering the way we see trust and transparency in business interactions. Beyond bitcoin, its decentralized and tamper-resistant nature has consequences. Only a few industries, like supply chains, identity verification, and digital rights management, may profit from the safe and unchangeable record of a blockchain.

In the future, the fusion of these technologies may provide even more amazing results. Imagine intricate, optimized structures being produced by 3D printers and AI-powered design tools that were previously inconceivable. In the era of the Internet of Things (IoT), blockchain transactions between machines might make data integrity possible and enable new levels of automation. These improvements come with difficulties and moral dilemmas, though. Automation's ability to replace jobs, data privacy difficulties, 3D printing's implications for intellectual property, and the environmental effects of mass manufacturing are all significant challenges that need to be properly considered.

Future AI, 3D printing, and blockchain integration will probably necessitate cooperation between governments, businesses, and academic institutions. Regulators must support innovation while preserving social interests, according to policymakers. To promote interoperability and security, industry leaders must band together to set standards and best practices.

In conclusion, the development of AI, 3D printing, and blockchain technology promises to usher in a time when the possibilities are

endless. We have the chance to build a more effective, fair, and linked society by utilizing the promise of these technologies while being aware of their drawbacks. The secret rests in our capacity to properly and imaginatively guide these technologies toward a more promising future for everybody.

SECOND PRIZE(SILVER MEDAL) - 2023

"INCREASING ROLE AND IMPORTANCE OF ADVANCED TECHNOLOGIES LIKE ARTIFICIAL INTELLIGENCE, BLOCK CHAIN TECHNOLOGY, 3-D PRINTING IN DRUGS AND PHARMACEUTICAL INDUSTRIES"

SYNOPSIS

In the relentless march of progress, technology is leading us into a transformative era of remarkable progress. This essay explores the profound impact of advanced technologies, including artificial intelligence (AI), blockchain, and 3D printing, on the pharmaceutical and healthcare industries. The role of AI in pharmaceutical research and development is discussed, highlighting its use in data-driven insights, drug discovery, clinical trials, and personalized treatments. The essay emphasizes the collaborative efforts of key pharmaceutical players in investing billions of dollars in AI initiatives. Blockchain technology is examined as a safeguard against counterfeit drugs, streamlining clinical trials, and combating misinformation in healthcare. Its potential applications in drug development and manufacturing are explored, with examples of leading pharmaceutical companies adopting blockchain solutions. The emerging market for 3D printed drugs is detailed, with a focus on personalized medicine, precise dosing, and technological advancements. The essay highlights the market's growth potential and the pivotal role of 3D printing technology in accelerating drug development and manufacturing.

Keywords: Artificial Intelligence, Blockchain Technology, 3D Printed Drugs, Personalized Medicine, Pharmaceutical Industry.

Increasing role and importance of advanced technologies like artificial intelligence, block chain technology, 3-D printing in drugs and pharmaceutical industries

"विकासस्य मार्गे प्रौद्योगिकी प्रधाना"

"On the path of progress, technology leads the way." In the ever-evolving tapestry of history, the threads of innovation and progress have woven together a narrative that spans centuries.

In an address that stirred the corridors of technology forums, Prime Minister Narendra Modi's words during the G20 Digital Economy Ministers' Meet echoed the essence of a paradigm shift. The world, he emphasized, holds within its grasp the power to build an ecosystem of technology-based solutions, a realm where the challenges that humanity faces can be met head-on. The four C's - conviction, commitment, coordination, and collaboration, he affirmed, are the guiding stars illuminating the path towards harnessing these technologies for the collective good. The message is clear: the digital realm is not just a playground of innovation but a battlefield for transformation that demands nothing short of unity and dedication. With the symphony of connectivity conducted by technology, the potential for inclusive and sustainable development has transcended mere possibility to become an inevitable reality. PM Modi's assertion that technology has united us like never before stands as a testament to the universal relevance of these advancements.

The confluence of innovation, precision, and personalized care has not only set the stage for transformative breakthroughs but has also earned global recognition for its profound implications. It is no coincidence that India, with its diverse landscape and vibrant population, has emerged as a crucible for testing groundbreaking solutions. The CoWIN platform's role in administering over 2 billion vaccine doses serves as an exemplar of technology's power to revolutionize healthcare. Prime Minister Modi's declaration that India's experiences and achievements are global treasures echoes through the launch of the online Global Public Digital Goods

Repository, aptly termed the India Stack. This repository stands as a beacon of digital inclusion, ensuring that the developing world is not just a spectator but a stakeholder in this unfolding digital narrative.

The pharmaceutical industry holds a crucial position as it engages in the exploration, formulation, production, and widespread distribution of medicinal solutions. A remarkable surge has marked its trajectory over the last couple of decades, with the global pharmaceutical revenues soaring to an astounding 1.48 trillion U.S. dollars in the year 2022 (1). Emerging as a prominent provider of economically efficient medications, India caters to approximately 20 percent of the worldwide demand for pharmaceuticals in terms of quantity. Remarkably, the Indian healthcare and pharmaceutical sector have been a frontrunner in global growth, projected to experience an astonishing 754 percent expansion from 2017 to 2060. India's forte has long resided in generic drugs, which substantially drove more than 70 percent of the total market revenue in the year 2018 alone (2). The transition to Industry 4.0, marked by interconnectedness, automation, and technologies like Internet of Things (IoT), AI (Artificial Intelligence), and three-dimensional (3D) printing, is revolutionizing manufacturing. This evolution leads to smart factories, data-driven decisions, and enhanced efficiency across diverse sectors.

Pharmaceutical AI technology entails the strategic deployment of AI methodologies and algorithms within the dynamic fields of pharmaceutical research, drug development, and healthcare. This innovative domain harnesses the power of machine learning, deep learning, natural language processing (NLP), and a spectrum of other AI techniques to effectively navigate and analyse vast datasets. The overarching objective is to distill meaningful insights, anticipate trends, and offer well-informed predictions in the intricate landscape of the pharmaceutical sector. AI and its counterpart, machine learning, are steadily making inroads into the landscape of pharmaceutical research and development, ushering in a new era of data-driven advancements.

AI's Trailblazing Impact on Pharmaceutical Innovation: Collaborations and Transformations

AI has ushered in a transformative era for the pharmaceutical and drug development sector in recent years, touching various facets of product advancement. Key players like GSK, Pfizer, and Merck & Co. have already engaged in collaborative ventures with AI-focused firms, and this trend is expected to intensify. Industry projections underline that the pharmaceutical field is projected to invest around US dollars 3 billion in AI initiatives by 2025.

Janssen, a proactive player in the field, has embraced the potential of AI across different realms of drug development. From uncovering potential drug targets to optimizing clinical trials, Janssen is actively exploring AI's applications throughout its drug development endeavours. The versatile utilization of AI spans domains like drug discovery, designing clinical trials, patient identification, and even streamlining manufacturing processes. As of the current year (2023), Janssen is actively engaged in more than a hundred ongoing AI projects. Meanwhile, Lonza is proactively immersing itself in the digital transformation of manufacturing through strategic employment of data, machine learning, and artificial intelligence applications. AstraZeneca, a prominent name, has established collaborations with over a hundred esteemed pharmaceutical partners and AI experts since 2015. These partnerships are driving the integration of machine learning into the identification and creation of innovative therapeutic solutions for chronic conditions like renal disease and idiopathic pulmonary fibrosis. Moreover, AstraZeneca is harnessing the power of AI and data science across its research and development initiatives. Partnering with Viking Therapeutics, they are expediting the development of non-alcoholic steatohepatitis (NASH) drugs, and in collaboration with the renowned Illumina, they are unveiling new horizons in drug discovery through advanced sequencing techniques (3). **Figure 1** delineates the pivotal domains within the pharmaceutical sector where AI is being harnessed to bring about transformative change. AI plays a pivotal role in drug discovery and development, predicting molecule properties and identifying potential candidates to reduce time and costs. Algorithms analyse biological data to pinpoint drug targets, particularly effective for specific diseases. Predictive analytics uses AI to forecast the success or failure of drug candidates by assessing various factors. AI

streamlines clinical trials by identifying patient groups with the most potential benefits from a drug. It also reimagines existing drugs for new therapeutic uses, saving time and costs. Personalized treatments are enabled by AI's analysis of patient data, while medical image analysis aids disease diagnosis and treatment. However, human validation and oversight are crucial to ensure ethical standards and patient safety.

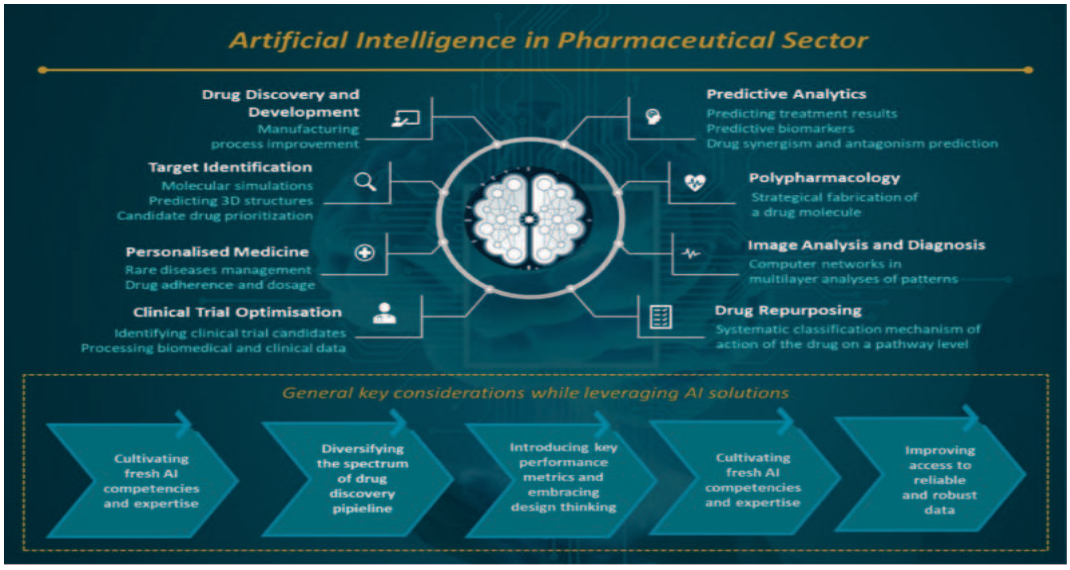


Figure 1: AI applications and vital considerations in the pharmaceutical domain

Charting Progress: The Prospective Trajectory of Tech and AI in Pharma

The future trajectory of technology and AI within the pharmaceutical industry holds immense promise, characterized by profound transformations across diverse sectors. As technology's influence deepens, its applications are tailored to address sector-specific challenges, optimize operations, and deliver substantial value to distinct stakeholders. Anticipating the future of AI in the

pharmaceutical realm unveils a landscape of remarkable change, poised to revolutionize fundamental aspects of drug discovery, development, and healthcare provision.

Presently valued at nearly 100 billion U.S. dollars, investments in this sphere are projected to surge by a staggering 2000% by the year 2030, reaching a monumental sum of almost two trillion U.S. dollars. A significant paradigm shift is anticipated as approximately half of the global healthcare enterprises embark on implementing strategic AI initiatives by the year 2025. Notably, industry experts underscore the indispensability of AI in shaping future business operations. The journey forward will see the continuous integration of AI and machine learning into drug discovery and manufacturing processes. As AI tools progressively become more accessible, they are poised to seamlessly integrate into the very fabric of pharmaceutical and manufacturing operations. In the coming years, the pharmaceutical landscape is set to be characterized by a harmonious blend of AI and human expertise, redefining industry practices and augmenting the realization of unprecedented potential. In the forthcoming pharmaceutical landscape, AI's influential prowess will prominently feature, marking a new epoch of innovation, enhanced efficiency, and patient-centric solutions.

The Impact of AI on Drug Development: An FDA Perspective

The United States Food and Drug Administration (USFDA), tasked with ensuring drug safety and efficacy, has turned its focus to the expanding use of AI and machine learning (ML) in drug development. In a recent move, the FDA released a discussion paper on 10th May 2023 on the topic, inviting feedback to foster dialogue and enhance mutual learning. The discussion paper outlines AI/ML applications across drug development stages, from drug discovery to clinical trials, manufacturing, and safety surveillance. The FDA acknowledges concerns like biases in data, transparency of models, privacy, and reproducibility. It aims to establish standards and practices for AI/ML in drug development. The FDA aims to establish standardized practices, seeking stakeholder engagement for a balanced regulatory approach. The FDA's engagement signals a transformative era in drug

development where AI and ML hold both potential and challenges, underlining the agency's vital role in navigating this evolving landscape (4).

Blockchain Technology: A Catalyst for Change

The unprecedented global upheaval caused by the coronavirus (COVID-19) pandemic had far-reaching effects on countless lives and economies. One of the hardest-hit sectors was healthcare, particularly elective medical procedures, which suffered disruptions that reverberated through the broader industrial landscape. However, a silver lining emerged from this crisis—a notable surge in the adoption of innovative technologies, with blockchain technology at the forefront. Known for its robust features like cross-checking, encryption, and decentralization, blockchain emerged as a formidable solution to safeguard the integrity of medical data (5). The response was swift as countries worldwide quickly integrated blockchain solutions into healthcare facilities, enhancing operational planning and resource allocation. A standout transformation occurred in the management of clinical trial data. This technology revolutionized the process by minimizing delays in regulatory approvals and streamlining communication across various stakeholders in the supply chain. This catalytic effect significantly propelled market growth, with the clinical trials sector accounting for 18% of the 2020 blockchain technology market share in healthcare. The diverse applications of blockchain, particularly in elevating the quality of clinical trials, fuelled this growth.

Another remarkable application was the development of blockchain-based tracking systems aimed at combatting the spread of misinformation—a crucial need during the pandemic. By 2020, the blockchain technology in healthcare market had reached a valuation of US dollars 281 million. Forecasts predict an astonishing Compound Annual Growth Rate (CAGR) of 52.1% from 2021 to 2027, propelled by the growing integration of the IoT in healthcare, further amplifying the demand for blockchain (6).

The pharmaceutical industry, a linchpin of global progress, plays a vital role in patient well-being through experimental treatments and maintaining drug quality. Challenges in securing the supply chain

against counterfeit goods, particularly in developed nations, have raised concerns. Here, blockchain emerges as a potential answer, particularly in drug development and manufacturing. Blockchain-driven Drug Management Schemes (DDCS) hold promise in tackling illicit drug trade. Industry giants like Sanofi, Pfizer, and Amgen have led the way with collaborative pilot projects utilizing blockchain-based DDCS to authenticate and evaluate experimental drugs. **Table 1** provides a summary of several blockchain solutions within the healthcare sector.

Table 1: Some of the Innovative Blockchain Solutions in Healthcare (7).

MediLedger	A widely recognized blockchain platform enabling businesses within the prescription drug supply chain to verify the legitimacy of medications, validate expiration dates, and access other critical information
Dermonet	An online dermatological consultation platform built on blockchain technology, incorporating a teledermatology surveillance device to provide dermatology support and guidance to patients
Proactive aging	A network based on blockchain technology that encourages and supports active living among elderly individuals
FHIRChain	An intelligent healthcare system built on smart contracts, enabling the exchange of clinical healthcare data
Healthcare	A currency system based on tokens, utilized for tracking information in the context of hospital employees, the stakeholders include doctors, health plans, and insurance companies and other relevant entities
Connecting Care	A record-sharing platform based on blockchain technology accessible across multiple English cities. Within a diverse healthcare organization, Connecting Care is employed to safeguard hospital and medical record data. It incorporates an access control list to ensure that only authorized users can access the clinical system
Ethereum-based framework	For incorporating the functionalities of smart contracts within the blockchain

Blockchain's Secure Transformation: Redefining Pharma Supply Chains and Patient Care

Blockchain's secure and unchangeable record, strengthened by digital signatures and agreement-based validation, guarantees the authenticity and safety of transactions. Its decentralized structure safeguards data integrity across different servers, mitigating cyber threats. The surging market value of blockchain stems from its trustworthiness, security, and capacity to boost efficiency. By streamlining processes and reducing intermediaries, blockchain effectively cuts costs. This transformative potential is especially evident in the pharmaceutical supply chain and drug development, piloting in a more secure and transparent era.

Further, innovative healthcare systems built on blockchain are poised to remotely monitor patients and manage complex medical scenarios, such as cancer care. Leveraging smart contracts and blockchain mechanisms, these systems guarantee patient data authenticity and privacy within advanced medical facilities and outpatient settings. Notably, blockchain holds promise for a comprehensive medical approach, spanning from chronic conditions like cancer to surgeries and aging-related care. Moreover, housing DNA data on blockchain could enable sophisticated cross-border genomic analysis, benefitting drug companies, manufacturers, and biomedical researchers.

The modern computer technologies, led by blockchain, has not only fortified the pre-existing capabilities of the pharmaceutical and healthcare sector but has also introduced novel dimensions. Notably, the IoT has empowered doctors and medical practitioners to achieve early and accurate diagnoses of various ailments, enhancing patient care and outcomes. In essence, the intersection of blockchain technology with the pharmaceutical industry presents a landscape of remarkable progress. From transforming clinical trials and enhancing data security to combating counterfeit drugs and revolutionizing patient care, blockchain's potential is rewriting the future of pharmaceuticals, unfolding a dynamic global health arena. **Figure 2A** outlines the fundamental characteristics of blockchain technology within the pharmaceutical and healthcare domains.

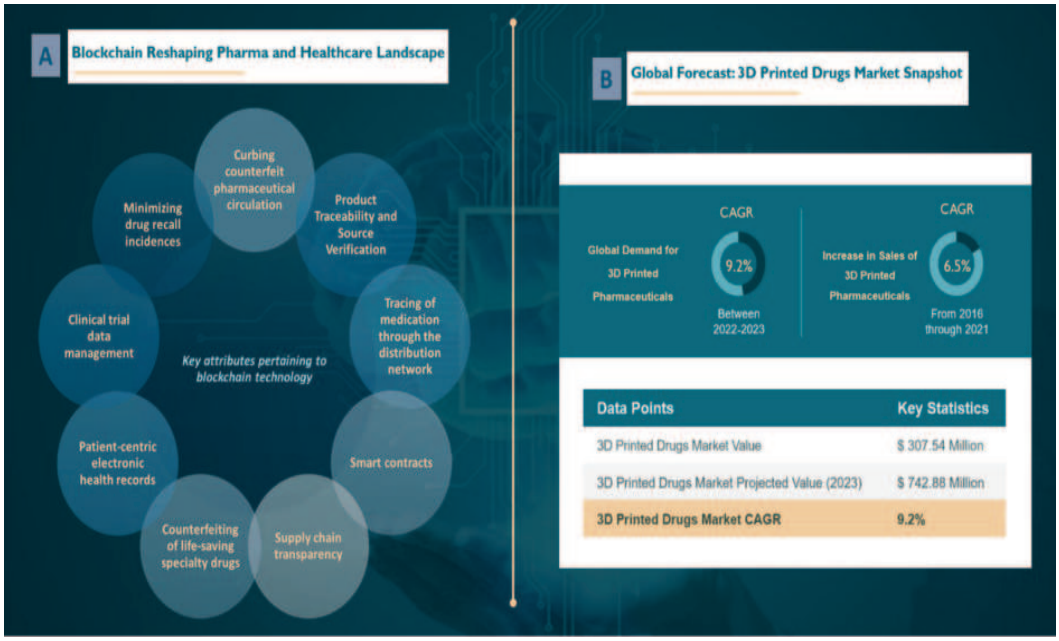


Figure 2: (A) The attributes that are crucial to blockchain technology's role in the pharmaceutical and healthcare landscape. **(B)** Overview of global forecast for the 3D printed drugs market.

Advancing Drug Manufacturing: The 3D Printing Paradigm

The pharmaceutical industry has witnessed rapid growth in the global market for 3D printed drugs, leveraging innovative 3D printing technology to create personalized drug formulations that enhance effectiveness and minimize adverse effects. The expansion of this market is propelled by the rising demand for tailored medicines, precise dosing, and technological advancements. Its main objective is to introduce a novel and effective approach to drug manufacturing, ultimately leading to improved patient outcomes and reduced healthcare expenses.

Categorizing the Global Market: Products, Applications, and Geographical Regions

The worldwide market for 3D printed drugs is categorized based on product types, applications, and geographical regions. In terms of technology, it is segmented into fused deposition modelling (FDM),

inkjet printing, zipdose technology and stereolithography. Application-wise, it spans across areas like orthopaedics, neurology, dental care, and other medical fields. According to Future Market Insights research, the global demand for 3D printed pharmaceuticals is projected to grow at a CAGR of 9.2% between 2022 and 2032, reaching a total market value of US dollars 307.54 million in 2032. Sales have shown significant growth from 2016 to 2021, with a CAGR of 6.5% **(Figure 2B)** (8).

The neurology sector emerged as the market leader, commanding a dominant share of 49.84% in 2022. An instrumental event occurred in August 2015 when the USFDA granted approval to Aprecia Pharmaceuticals' SPRITAM (levetiracetam) tablets for epilepsy treatment. This sparked interest and investments from pharmaceutical firms, thereby fostering market expansion. The surge in neurological disorders like Parkinson's disease further fuels this segment's growth. A noteworthy breakthrough transpired in April 2022, as German and Dutch scientists employed 3D printing technology, namely FDM, to create the Mini-Floating-Polypill for Parkinson's therapy. In contrast, the field of orthopaedics presents challenges necessitating fresh approaches to enhance patient outcomes in intricate procedures. Complications, notably a high infection rate, have led to prolonged suffering and functional loss post orthopaedic surgeries. In this context, orthopaedic drugs hold the potential to combat postoperative infections, thus propelling market growth.

Regional dynamics indicate North America's prominence, seizing a commanding 38.23% share in 2022. This dominance is attributed to the surge in chronic ailment incidences, robust domestic healthcare infrastructure, substantial investments in research and development (R&D), and the pervasive integration of technological advancements within the region. Meanwhile, the Asia Pacific region is expected to experience the most rapid expansion. China and Japan's substantial strides in incorporating 3D printed drug methodologies play a pivotal role. Additionally, emerging economies like India and Australia are actively developing healthcare infrastructure, R&D capabilities, and clinical frameworks, positioning the Asia Pacific market for worthwhile prospects and sustained growth across the forecasted period (9).

Pharmaceutical 3D printing's intelligent trajectory: The modern catalogue

The rapid expansion of the global 3D Printed Drugs market is fundamentally propelled by the escalating desire for personalized medicines. These medical treatments are finely tailored to the unique genetic makeup, lifestyle, and environmental factors of individual patients. The advantages of personalized medicines are noteworthy, including heightened effectiveness, minimized side effects, and enhanced patient adherence to treatment regimens. This trend harmonizes seamlessly with the capabilities of 3D printing technology, which excels at creating customized drug formulations featuring precise dosing and controlled release characteristics. This exceptional precision renders 3D printing an ideal fit for crafting personalized medications that cannot be achieved through traditional manufacturing methods. The surge in demand for personalized medicines is significantly fuelled by the prevalence of chronic diseases and the growing need for pinpointed drug delivery. Conditions such as cancer, diabetes, and cardiovascular disorders can substantially benefit from personalized medications, leading to improved patient outcomes and enhanced quality of life. The strategic delivery of drugs to targeted sites in the body not only reduces the necessary dosage but also minimizes side effects, thus enhancing patient compliance and overall treatment effectiveness.

Equally significant, the evolution of technology plays an instrumental role in driving the growth of the global 3D printed drugs market. Over the course of its development, 3D printing technology has achieved remarkable milestones, culminating in the capability to create intricate and highly precise drug formulations. This level of precision opens doors to tailoring drugs to individual patients, which not only enhances their efficacy but also mitigates potential side effects. What is even more remarkable is the acceleration in the production of 3D printed drugs, a consequence of these technological advancements. This has significantly shortened the timelines required for drug development and manufacturing. This acceleration empowers pharmaceutical companies to introduce new drugs into the market at a much faster pace. The scope of 3D printing technology has also expanded beyond traditional materials like plastics and metals. It now encompasses a wide array of substances, including biocompatible

materials such as hydrogels and polymers. These materials are not only compatible with the human body but also hold potential for targeted drug delivery. The global 3D printed drugs market is poised for substantial growth driven by the surging demand for personalized medicines and continuous advancements in 3D printing technology. This convergence of factors is fuelling the market's upward trajectory.

However, the sector faces challenges including high expenses, regulatory complexities, and the necessity for further research and development. Pharmaceutical 3D Printing introduces an array of distinct technologies that collectively enable the printing of nearly any imaginable medicine. To effectively integrate AI with pharmaceutical 3DP, it is crucial to acknowledge the diversity and challenges within these techniques (10). On the upside, opportunities encompass the creation of novel drug formulas, market growth, and revolutionary drug delivery techniques. Moreover, 3D printing technology holds the potential to establish fresh revenue streams for pharmaceutical enterprises.

Concluding Remarks

Harmony in Progress: The Future Awaits

The convergence of advanced technologies, such as AI, blockchain, and 3D printing, has ignited a paradigm shift in the pharmaceutical and healthcare domain. Prime Minister's call for unity in technological adoption resonates, emphasizing the transformative potential of technology-driven solutions to global challenges. AI's integration into pharmaceutical research and development is reshaping drug discovery, manufacturing, and clinical trials. Blockchain emerges as a sentinel against counterfeit drugs, enabling secure data sharing and streamlined processes. 3D printing's personalized drug formulations and rapid advancements usher in an era of tailored medicines. This symphony of innovation not only propels pharmaceutical growth but also heralds an inclusive and efficient healthcare future.

Key Highlights

1. The Prime Minister's call for unity in technology-driven solutions underscores transformative potential.
2. AI's strategic deployment redefines pharmaceutical research and development through data-driven insights.
3. Blockchain safeguards drug integrity, enhances clinical trials, and combats misinformation in healthcare.
4. 3D printing revolutionizes pharmaceuticals with personalized drug formulations and rapid progress.
5. Pharmaceutical industry's global revenue surge underscores its pivotal role in patient care.
6. AI's transformative impact on drug development evident through collaborations and industry investments.
7. Blockchain's secure record-keeping transforms clinical trials and drug supply chains.
8. IoT-driven diagnosis and patient care empowered by blockchain and technology.
9. The synergy of AI, blockchain, and 3D printing propels pharmaceuticals toward tailored solutions.
10. A harmonious era of technological advancement unfolds, promising a patient-centric and efficient healthcare landscape.

So, where is all this headed?

Well, these technologies are like a powerful symphony, changing the way we do healthcare. It is not just about getting better; it is about getting better faster and safer. In this fast-paced world, these innovations are breaking down old barriers, and they are doing it in a way that is smarter, more efficient, and more patient-centred. It is a new era of healthcare, driven by technology, and its changing lives for the better.

"As the world unites in the pursuit of technological excellence, the future of pharmaceuticals is not just a promise but a resounding reality."

B. V. Patel Essay Competition History at a Glance

The trust conducts an all India level Essay Competition every year as one of its activities. The selection of the subject depends on the importance and the current happenings in the Sector. Any one interested in drugs and pharmaceuticals, academically, industrially or otherwise, can participate in the competition. The entries are generally invited in the month of July/August. The essays are evaluated independently by a panel of judges comprising of the expert luminaries of industry and academy. The essays of the winners are printed and distributed during the IPC since 1977.

The year-wise subjects chosen for the Essay Competition :

Year		Subject
1977	-	Good Manufacturing Practice in Parenterals
1978	-	Indian Pharmacopoeia for the Future
1979	-	Documentation and Record Keeping in Drug Manufacture
1980	-	Drug Distribution
1981	-	Review and Modification of Drugs Legislation in India
1982	-	Industry Oriented Pharmacy Education - Its Means and Modifications
1983	-	Role of Testing Laboratories in Assurance of Quality Drugs
1984	-	Material Management in Pharmaceutical Industry
1985	-	Status & Prospect Of Research and Development
1986	-	Manufacture of Dosage Forms - Problems and Remedies
1987	-	Advances in the Technology of Industrial Pharmacy
1988	-	Role of Combination Products in Drug Therapy
1989	-	1. Continuing Education in Pharmacy
		2. Trends in Pharmaceutical Research

1990	-	Restructuring of Pharmacy Education
1991	-	Biotechnology in Pharmacy
1992	-	Role of Pharmacists on Stability of Pharmaceuticals
1993	-	ISO 9000 and its Applicability to Pharmaceuticals-A Pharmacists Perception
1994	-	Challenges and Opportunities in Pharmaceutical Research
1995	-	New Drug Delivery Systems - Indian Scenario
1996	-	Traditional Medicines - Sources of New Drugs
1997	-	Clinical Pharmacy in India - Emerging Facet of the Pharmacy Profession
1998	-	Community Pharmacy
1999	-	Revision of Indian Patents Act 1970 And its Impact on Availability and Cost of New Pharamceuticals
2000	-	Information Technology-Revolutionary Impact on Pharmaceutical, Sciences
2001	-	Aesthetic Design of A Manufacturing Unit in Compliance with National Regulatory Requriement and WHO - GMP
2002	-	Genomics and Proteomics: Treasure for Drug Discovery
2003	-	Pharmacy Education: Current Problems and Suggested Solutions
2004	-	Industrial Growth in Changing Scenario: Strategic Options for Small and Medium Enterprises (SMES)
2005	-	Roadmap to Globalization of Ayurveda as Recognized Healthcare System
2006	-	Prospects for CRO in next Five Years: Indian Capabilities
2007	-	Distribution of Pharmaceuticals and Drugs in India: Its Science, Commerce and Ethics
2008	-	Medical Devices: Opportunities For Indian Industry

2009	-	Steps to Revitalize Pharmacy Profession in India
2010	-	Innovation: Driver for Growth of Indian Pharma ?
2011	-	Vaccines In Healthcare: Indian Perspective And Potential
2012	-	Drug Affordability in India - Post 2005
2013	-	Patent - The Need for Efficient Handling of Disputes
2014	-	Pharmacists in a State of Mortification: Reasons, Responsibilities of Stakeholders and Remedy
2015	-	Pathway for Zero Defect Product and Production in Pharmaceutical Industry
2016	-	Clinical Trials in India and China: Advantages and Disadvantages
2017	-	Stem Cell Based Therapeutics: A Revolution Changing the Treatment Paradigm
2018	-	Advertising in Pharmaceuticals: Therapeutic or Toxic
2019	-	Drug Discovery: Opportunities and Challenges in using Artificial Intelligence
2021	-	Role of Pharmaceutical Research Scientist and Industry in the Pandemic
2022	-	Role of Pharmacy Institutions in Innovation and Start-ups to make AtmaNirbhar Bharat

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