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Future Trends in Pharmaceuticals: Investigation of the Role of AI in Drug Discovery, 3D Printing of Medications, and Nanomedicine

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A B S T R A C T S

The pharmaceutical sector has to deal with issues like high costs, difficult diseases, and the demand for tailored therapy. The transformational potential of AI, 3D printing, and nanomedicine is examined in this paper. Drug development is revolutionized by AI, which also predicts effectiveness and personalizes therapies. Tailors, prescriptions, and complex documents can all be 3D printed to help with compliance. Nanoparticles are used in nanomedicine to deliver drugs more precisely and enhance solubility. Future themes include AI-driven target identification and individualized treatment; the effectiveness and role of 3D printing in personalized medicine; and improved medication delivery through nanomedicine. These developments promise to alter healthcare, which will help a lot of people. The study results offers a thorough examination of upcoming trends in the pharmaceutical industry and similarly discusses developments in 3D printing and nanomedicine.

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1. INTRODUCTION

The impact of artificial intelligence and automation on a variety of sectors is an intriguing topic to debate given their rapid growth and advancement. A variety of issues, such as the rising price of drug development, the complexity of diseases, and the increased need for individualized medication, are posing difficulties for the pharmaceutical sector. Emerging technologies like artificial

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intelligence (AI), 3D printing, and Nano medicine have the ability to solve these problems and completely transform the pharmaceutical sector.

The main aims of this study are:

- To study the trend and role of Artificial Intelligence in drug development and discovery
- To study the potential changes in the field of drug discovery.
- To study the recent advancements in the field of drug development.

Deep neural networks and other advanced AI techniques have gained popularity and success, opening up new avenues for chemical space exploration. Their opacity makes it difficult to evaluate models for creativity, originality, and distribution of the chemical space covered. But these strategies also promise to open up previously unexplored chemical territory in fresh ways that do not rely solely on structural similarity (Vogt, 2022).

The National Institutes of Health has coined the term "nano-medicine" to describe the use of nanotechnology in the treatment, diagnosis, monitoring, and control of biological systems. Projects in nanomedicine are currently focusing on research into the rational delivery and targeting of pharmacological, therapeutic, and diagnostic substances. These involve locating exact targets (cells and receptors) linked to certain clinical disorders and selecting the proper nanocarriers to elicit the desired responses with the least rate of negative impacts. Key targets include malignancies (tumor cells and tumor neo-vasculature), dendritic cells, endothelial cells, and mononuclear phagocytes. Although some of the anticipated benefits are overstated, nanotechnology and nanoscience methods to particle design and formulation are currently starting to grow the market for numerous pharmaceuticals and are laying the groundwork for a very lucrative business sector. The logical design and surface engineering of nanoscale entities and vehicles for site- specific drug delivery and medical imaging will be highlighted in this article (Moghimi et al., 2005).

The process of finding new drugs will likely be profoundly impacted by systems biology. Understanding the entire range of molecular mechanisms describing an organism is one of its ultimate objectives. Even though this objective is still far off, the information and technology that are already available can already provide many helpful insights. The high attrition rate in drug discovery nowadays is one of the main challenges: many attractive candidates turn out to be hazardous or useless due to a lack of knowledge of the molecular mechanisms of the biological systems they target. A "systems" approach can aid in locating disease-related pathways and indicate potential drug side effects that could result in these issues, thereby enhancing the process of discovering new treatments (Apic et al., 2005). The pharmaceutical business has undergone a dramatic transition as a result of the integration of artificial intelligence in medication discovery and development. In this article, we look over integration areas, AI enforcement tools and methodologies, ongoing problems, and solutions (Paul et al., 2021).

The amount of health and "omics-related data" produced and stored has increased dramatically during the last few decades. In clinical trials, patient data can be gathered in real-time and examined using

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a variety of artificial intelligence (AI) techniques; mobile devices can also be utilized to enhance certain facets of disease diagnosis and treatment. AI can also be used to identify data-driven ideas for scientists, develop new pharmaceuticals or repurpose existing ones, diagnose ailments more quickly, and treat them more effectively. In this article, we talk about how AI is beginning to transform the life sciences industry (Leite et al., 2021).

With the integration of 3D printing, nanomedicine, and artificial intelligence (AI), the pharmaceutical industry is going through a transformative era. Chemical space exploration is being redefined by AI techniques, which open up new possibilities beyond structural similarity. The National Institutes of Health coined the term "nanomedicine," which refers to the precise targeting and delivery of therapeutic substances, especially in critical areas like dendritic cells and malignancies. By providing a comprehensive understanding of molecular mechanisms, systems biology helps to reduce the high rates of attrition in drug discovery. AI's incorporation into drug discovery and development ushers in a new era of efficiency by addressing complex diseases and cost constraints.

With tailored treatments and targeted medication delivery positioned to help a broad range of people, these developments hold the potential to completely transform the healthcare industry. The significant influence these innovations have had on the pharmaceutical industry is highlighted by this comparative analysis.

2. Proposed Work

As, artificial Intelligence is a subject of wide research and many breakthroughs are made in its research works. Universities are at the forefront of cutting-edge research in artificial intelligence (AI) in the modern academic environment, particularly in the fields of machine learning (ML) and deep learning (DL) especially in the Brain Computer Interface field. The creation and use of AI methods for medical applications, such as breast cancer and Covid-19 prediction, is a major area of focus. This study is a key development in the use of AI's analytical powers to improve healthcare systems.

Furthermore, this study aims to offer a comparative examination of AI's functions and uses across different fields. It looks into the applications of AI in marketing, finance, customer service, driverless cars, and healthcare. AI-driven algorithms are essential to the financial industry for risk assessment, fraud detection, and investment strategy optimization. Artificial Intelligence (AI) is essential for the development of sophisticated computer vision systems and natural language processing capabilities in autonomous cars, which enable safer and more effective navigation. This study carefully examines present and potential developments in AI as well as its uses in the field of medicine. With an eye toward their potential to lead to advancements in healthcare, researchers are monitoring the development of ML algorithms and DL approaches. The paper also explores recent developments, including how AI is being combined with genomics and personalized medicine, which has the potential to further individualize patient care (Fig. 1).

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Fig.1. AI relationship to medical Industry

The current pattern of ongoing artificial intelligence projects presents a dynamic landscape of applications in many industries. With efforts concentrating on utilizing machine learning and deep learning for precise predictions in fields like breast cancer and Covid-19, artificial intelligence (AI) is transforming disease detection and diagnosis in the healthcare industry. Researchers hope to improve patient outcomes and early intervention by utilizing algorithms to assess clinical data and medical pictures. Furthermore, the pharmaceutical industry is seeing a rise in AI-driven drug discovery programs, in which sophisticated algorithms comb through enormous datasets in search of promising molecules and quicken the development process. AI is revolutionizing industries outside of healthcare, such as banking, with programs focused on risk assessment, fraud detection, and investment strategy optimization.

Furthermore, continuing initiatives are expanding the capabilities of natural language processing and computer vision in autonomous cars to improve communication, safety, and navigation. AI is also changing marketing and customer service, with initiatives aimed at automating different parts of customer contacts, personalizing user experiences, and building chatbots. The current wave of AI initiatives, taken as a whole, shows how broad and active the field is and how artificial intelligence has the potential to revolutionize a wide range of fields and applications.

2.1. AI's Functions & applications

Artificial Intelligence (AI) is revolutionizing drug discovery by changing the way pharmaceutical research is carried out. Researchers can now identify possible drug candidates with previously unheard-of speed and accuracy by sorting through massive volumes of biological data using artificial intelligence (AI) and machine learning models. Drug development can proceed much faster in the early stages thanks to its ability to analyze complex molecular structures, predict their behavior, and simulate interactions with target proteins. AI is also capable of sorting through databases and scientific literature to uncover important insights that might otherwise go unnoticed (Figs. 2 and 3).

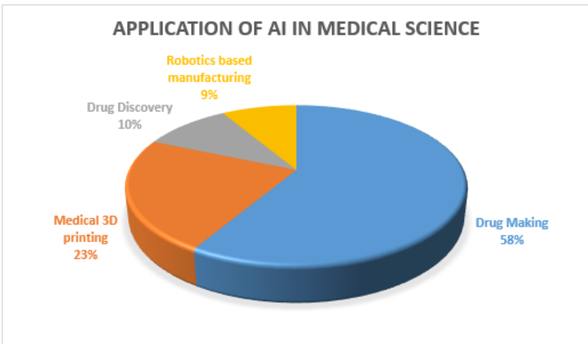

Fig. 2. Pie-chart for AI application in medical field

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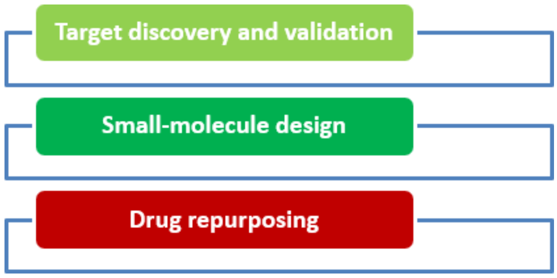

Fig. 3. AI applications in drug discovery

As shown in Fig. 2, some applications of artificial intelligence include drug discovery, 3D printing, drug manufacturing, and robotics-based manufacturing in industries and research centers. The main use of AI is in drug making, as AI-based systems can be used to make drugs, calculate requirements, and provide assistance.

Personalized medicine is facilitated by this technology, which allows for the customization of treatments for individual patients according to their genetic composition and unique disease features. AI also makes it easier to repurpose already-approved medications for novel therapeutic indications, which could hasten the release of new treatments for a range of illnesses. All things considered, the use of AI in drug discovery not only speeds up the process but also has the potential to find cutting-edge treatments that could transform medicine and save a great deal of lives.

2.2. Artificial Intelligence in Drug Discovery

AI is being used to address all aspects of drug discovery, from target identification to drug design and development. Each stage of drug discovery involves a certain timeline that can be cut down with the help of artificial intelligence. AI- powered tools can be used to:

i. Analyze large datasets of genomic and proteomic data to identify genes and proteins that are involved in disease.
ii. Screen millions of potential molecules to identify those that are most likely to be effective against a particular disease target.
iii. Predict the efficacy and safety of drugs.
iv. Personalize drug treatment regimens.

The diseases affecting humans are increasing tremendously whereas the drugs which are available to treat or cure are very much minimal. But this kind of scenario will not be present in the future because of the combination of artificial intelligence and the pharmaceutical industry which results in faster discovery of drugs with increased clinical outcomes.AI is already being used by pharmaceutical companies to develop new drugs. For example, the company 'Atomwise' uses AIto design new molecules that target specific proteins involved in cancer. The company has successfully developed a number of new drug candidates, and one of its drugs is currently in clinical trials. Artificial intelligence (AI) is the use of computer systems to perform tasks that normally require human intelligence, such as learning, reasoning, and decision-making. AI has been making inroads in drug discovery for a good part of the last decade, as it can help accelerate the process of finding new drugs, similarly, new biomedical innovation, reduce the costs and risks of failure, and enable the exploration of novel chemical and biological spaces (Vogt, 2022).

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2.3. 3D Printing of Medicines

Pharmaceuticals and clinical pharmacy practice are undergoing a paradigm shift as a result of three-dimensional (3D) printing, moving away from the old mass manufacture of drugs and toward individualized, personalized therapeutic products. By enabling the on-demand design and fabrication of flexible formulations with individualized dosages, forms, sizes, drug release, and multi-drug combinations, the concept has the potential to benefit patients, pharmacists, and the pharmaceutical business alike. This marks a turning point in the history of 3D printing technology in the pharmaceutical industry, necessitating the participation and assistance of healthcare professionals, including pharmacists, doctors, nurses, and pharmacy technicians, among others, in order to facilitate the wider adoption of the technology in clinical practice.

3D printing is a manufacturing process that can be used to create three-dimensional objects from a digital file. 3D printing is being used to develop new ways to manufacture medications. For example, 3D printing can be used to create personalized medications tailored to each patient's specific needs.

3D printing can also be used to create complex dosage forms that are difficult or impossible to produce using traditional methods. For example, 3D printing can be used to create medications that have a specific shape or that release the drug in a controlled manner.

i. Rapid prototyping: 3D printing can facilitate the rapid development and testing of new drug formulations and delivery systems without requiring expensive molds or equipment. This can speed up the time-to-market and reduce the costs of drug development (Suresh and Basu, 2008).
ii. On-demand production: 3D printing can allow agent that can inhibit the growth and division of cancer cells. The nanoparticles can enhance the solubility, stability, and delivery of paclitaxel, as well as reduce its toxicity and side effects.

2.4. Nanomedicine

Recently, the term "nanomedicine" has been used to describe the use of nanotechnology for the treatment, diagnosis, monitoring, and control of biological systems. Projects in nanomedicine are focusing on the rational delivery and targeting of pharmacological, therapeutic, and diagnostic substances. These entail the selection of appropriate nanocarriers and the identification of precise targets linked to particular therapeutic diseases in order to maximize desired responses and minimize unwanted consequences.

Nanomedicine is a field of science that uses nanoparticles to deliver drugs to specific targets in the body. Applications of nanotechnology for treatment, diagnosis, monitoring, and control of biological systems have recently been referred to as “nanomedicine” by the National Institutes of Health (Moghimi et al., 2005). Nanoparticles are small particles that have a size of 1-100 nanometers. They can be made of different materials, such as metals, polymers, or lipids. Nanoparticles can be used to deliver drugs to cancer cells, to improve the solubility of drugs, or to

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protect drugs from degradation. They are also being investigated for use in gene therapy and vaccination.

2.5. Drug repurposing

AI can help find new uses for existing drugs by mining and integrating data from various sources, such as clinical trials, electronic health records, patient registries, and social media. AI can also help predict the potential benefits and risks of repurposing drugs for different indications, populations, or combinations (Leite et al., 2021). In addition, AI can help to build a medicine intended to treat disease in specific parts of the body (Fig. 4).

Fig. 4. AI in drug Discoveries

Some examples of AI-based drug discovery platforms are:

Exscientia: A company based in Oxford, UK, that uses an AI-driven platform to design small-molecule drugs from scratch. The platform combines computational chemistry, machine learning, and automated synthesis to generate and optimize drug candidates that meet predefined objectives. Exscien2tia claims to have the first two molecules designed with the help of AI to enter clinical trials: a selective serotonin reuptake inhibitor (SSRI) for obsessive-compulsive disorder (OCD) and an A2 receptor antagonist for oncology (Denys et al., 2004) (Fig. 5).

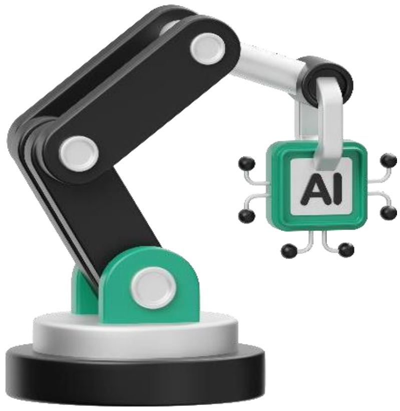

Fig. 5. Robotic arm & AI relation

In the future, artificial intelligence (AI) in the drug discovery industry will be able to control a robotic arm through the use of ML-based algorithms and brain-computer interface techniques. In the most recently developed industries, artificial intelligence is essentially in charge of both drug discovery and drug manufacturing processes. Here, robotics-based manufacturing is crucial, and the methods used in such automation activities include a robotic arm that uses artificial intelligence and machine learning-based algorithms.

Insilico Medicine: A company based in Hong Kong that uses an AI-powered platform to discover new drugs for aging and age-related diseases. The platform uses deep generative models, reinforcement learning, and transfer learning to create novel molecules with desired properties and biological activities. Insilico Medicine also uses AI to predict the biological age of patients and identify biomarkers of aging and disease (Johnson, 2006). Such predictions are useful to cure disease faster and generate disease according to the need of consumers.

Some of the applications of AI in drug discovery include:

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1. Target discovery and validation: AI can help identify and prioritize potential drug targets by analyzing large amounts of genomic, proteomic, and phenotypic data, as well as scientific literature and databases. AI can also help validate the relevance and ability of targets by predicting their interactions with molecules and their effects on biological pathways (Apic et al., 2005).
2. Small-molecule design: AI can help generate novel and diverse molecules that match desired properties and criteria, such as potency, selectivity, safety, and bioavailability. AI can use generative models, such as deep neural networks or requirements of the body of affected individual.
3. Benevolent AI: A company based in London that uses an AI-enabled platform to discover new drugs for various diseases. The platform leverages natural language processing (NLP), knowledge graphs, machine learning, and data mining to extract insights from scientific literature and data, identify novel targets and pathways, generate hypotheses, and design optimal molecules. Benevolent AI has several drug candidates in its pipeline for diseases such as Parkinson's disease, ulcerative colitis, sarcopenia, and glioblastoma (Reddy et al., 2017; Riar et al., 2020; Sinha et al., 1996; Suresh and Basu, 2008) (Fig. 6).

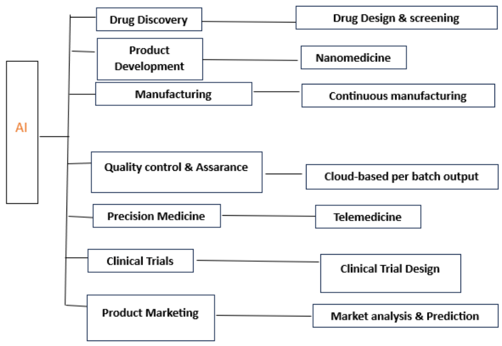

Fig. 6. Applications of AI in different pharma segments

3. Results and Discussion

In the realm of artificial intelligence, there are numerous applications and current trends in the healthcare sector. The health sector is expanding quickly, and given this tendency, there are a variety of opportunities for its future expansion.

3.1. ML algorithms in pharmaceuticals and drug discovery

Algorithms for machine learning (ML) are essential to many parts of the pharmaceutical business, such as drug development, manufacturing, and discovery. ML algorithms play the following important roles in these domains:

- Drug Finding:
  i. Compound Screening: To determine a chemical compound's potential as a drug candidate, machine learning models are able to evaluate large datasets of data. This can greatly expedite the preliminary screening procedure.
  ii. Virtual Screening: Without requiring animal testing, machine learning algorithms can be used to forecast a compound's affinity for a target protein. This enables the

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identification of possible therapeutic candidates. Target Identification: By comprehending the connections between genes, proteins, and illnesses, machine learning models are able to evaluate biological data and identify possible therapeutic targets.

- Drug cophore Simulation:

Pharmacophore models, which depict the necessary characteristics for a molecule to attach to a particular biological target, can be created with the help of machine learning. This aids in creating molecules with the appropriate characteristics.

- Drug Development and Enhancement:

By predicting which modifications are likely to improve a compound's properties (e.g., potency, solubility, toxicity), machine learning algorithms can help optimize lead compounds.

- Forecasting ADME Characteristics

The Absorption, Distribution, Metabolism, and Excretion (ADME) characteristics of possible drug candidates can be predicted by ML models, which aids in the identification of substances with a better likelihood of succeeding in clinical trials.

- Estimating Toxicology:

By predicting a compound's potential toxicity through data analysis, machine learning algorithms can assist in the identification of safer candidates for further development.

- Optimization of Clinical Trials:

By using specific criteria to identify potential candidates for clinical trials, machine learning (ML) can evaluate patient data and potentially shorten trial durations and costs.

- Customized Medical Care:

With the use of ML algorithms, medical records, including genetic data, can be analyzed to customize treatments for each patient, improving effectiveness and lowering side effects.

- Manufacturing of Pharmaceuticals:

By forecasting the ideal conditions for producing pharmaceuticals, increasing yields, and decreasing waste, machine learning (ML) can optimize manufacturing processes.

- Quality Control and Regulatory Compliance:

To guarantee adherence to legal requirements and preserve product quality, manufacturing processes can be monitored and managed using machine learning.

a. Nanoshells

A type of nanomaterial that consists of a silica core coated with a thin layer of gold. Nanoshells can be tuned to absorb or scatter light at different wavelengths, depending on the size and thickness of the core and the shell. Nanoshells can be used for various biomedical applications, such as optical imaging, biosensing, drug delivery, and photothermal therapy (Shen et al., 2013). For example, researchers from Rice University have developed nanoshells that can selectively target and destroy cancer cells by heating them up with near-infrared light.

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b. Nanobots

A term that refers to nanoscale devices or machines that can perform specific tasks or functions at the molecular level. Nanobots are still in the realm of science fiction (Bowman et al., 2007), but some researchers have proposed or demonstrated the feasibility of creating nanobots that can move, sense, communicate, or manipulate matter. For example, researchers from Arizona State University have created DNA nanobots that can open and close in response to external stimuli, such as pH or temperature (Lund et al., 2006). These nanobots could potentially be used for drug delivery, gene regulation, or molecular computing (Fig. 7).

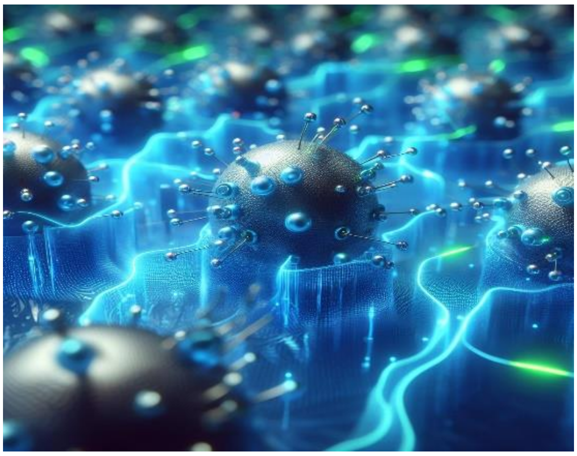

Fig. 7. A nanobot's illustration

And we can expect to see nanomedicine being used to:

- Deliver drugs to specific targets in the body.
- Improve the solubility of drugs.
- Protect drugs from degradation.
- Be used in gene therapy and vaccination.

These technologies have the potential to improve the lives of millions of people by making it possible to develop new and more effective treatments for diseases (Dowling, 2004).

3.2. 3D Printing in Pharmaceuticals

3D printing is a form of additive manufacturing in which a 3D object is built by depositing building materials in successive layers according to a predesigned 3D geometric structure. 3D printing of pharmaceuticals is a unique approach that allows for the manufacture of solid drug products in various shapes, geometric designs, strengths and spatial distributions.

Fig. 8. Medical 3D printing

Clinical pharmacy practice could undergo a transformation thanks to 3D printing. It can shift from the mass production of medicines using conventional methods to the on-demand synthesis of highly flexible and individualized dosage forms in small quantities. By offering special benefits including enhancing the safety and efficacy of therapies, this technology benefits patients, pharmacists, and the pharmaceutical business alike. The integration of this technology will be made possible by healthcare

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professionals, including pharmacists, doctors, and nurses. They will also be crucial in advising academics, the pharmaceutical business, and biotech companies on how to develop the sector utilizing 3D printing.

Some of the advantages of 3D printing of pharmaceuticals include:

- Customized Doses: Medication can be precisely fabricated with doses that are specific to each patient's needs thanks to 3D printing. This is especially important when patients might need certain dosages that are hard to get through traditional mass manufacturing.
- Complex Geometries: It is frequently difficult for traditional manufacturing techniques to produce medications in complex or intricate forms. Drugs with distinctive forms, structures, or delivery systems can be designed and produced thanks to 3D printing's exceptional ability to create complex geometries.
- Personalized medicine: Drugs can be made according to a patient's unique physiological traits or genetic composition using 3D printing. This degree of customization may result in less harmful side effects and more effective treatments.
- Combination Therapies: Using multiple active ingredients in a single dose is made easier with 3D printing, which is especially helpful for combination therapies. This makes it possible to treat several parts of an illness or condition at once.
- Decreased Manufacturing Waste: The necessity for mass production and packaging in traditional drug manufacturing processes frequently leads to excess waste. Because it only uses the materials required, 3D printing is more efficient in terms of waste reduction and environmental sustainability.
- Accelerated Drug Development: Drug formulations can be quickly prototyped and iterated upon thanks to 3D printing. As a result, the research and development stage of the process is accelerated, enabling pharmaceutical companies to launch new drugs more quickly.
- Increased Patient Compliance: Drugs can be created in patient-friendly forms, like chewable tablets or oral films, using 3D printing. This has the potential to improve patient compliance with recommended schedules, particularly when dealing with younger or older patients.
- Decreased Supply Chain Complexity: Large-scale manufacturing facilities and intricate supply chains are no longer necessary when pharmaceuticals can be produced on-site or as needed thanks to 3D printing. This is especially helpful in isolated or underdeveloped areas.
- Improved Research and Testing: High-accuracy models for drug testing and experimentation can be made thanks to 3D printing. To investigate drug interactions, scientists can create complex models of organs or tissues, which could result in the development of safer and more effective medications.

3.4. Hot trends in medical research with AI

As the figure illustrates, there are numerous research projects ranging from large-scale research projects to university-level research in areas such as cancer detection research using artificial intelligence (AI), such as breast cancer detection, plant disease detection, and

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medical imaging systems, and robotics in the healthcare industry, such as sister robots developed for hospitals during COVID-19, gas leakage prevention robots, emergency situation rescue robots, etc. These are just a few examples of the ongoing, globally popular research and development projects. Biomedical field research and brain-computer interface are expanding globally at a very quick pace. Brain-computer interface encompasses motor imaging, the prediction of motor neuron generating diseases like Leprosy, Epilepsy, ALS disease, etc. using machine learning approaches, their prevention, and the use of biomedical devices under global study for therapy (Figs. 9 and 10).

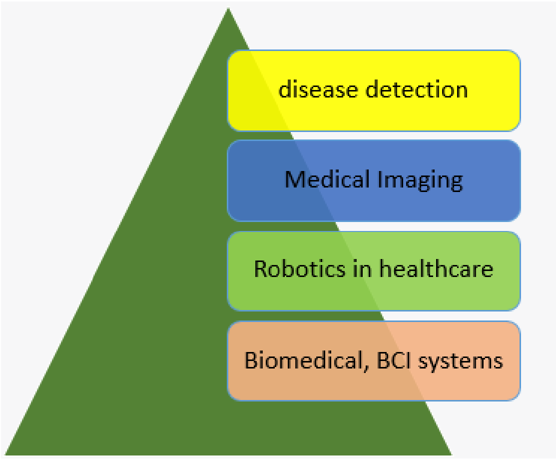

Fig. 9. Pyramid of AI in different fields

Fig. 10. Brain Computer Interfacing illustration

3.5. Future Trends

Although the application of AI, 3D printing, and nanomedicine in the pharmaceutical industry is still in its infancy, these technologies have the potential to completely alter how drugs are created, produced, and administered.

3.5.1. Artificial Intelligence & Drug Discovery market

Because AI reasoning can identify diseases, provide treatments for illnesses, and predict which creature infections will spread, it has profound implications for medication research. It has been demonstrated that artificial awareness advances drug discovery and development by assisting scientists in discovering new ways to treat diseases. In medicine, pharmacology, and biotechnology, prescription disclosure and improvement refer to methods for formulating, arranging, and obtaining a drug by identifying a naturally occurring target, such as a protein, molecule, quality, or receptor. Recently, drugs have been discovered by identifying the dynamic component of conventional therapies. As such, the first step towards identifying potentially inventive prescriptions and their beneficial uses is drug disclosure.

The global research data reveals (Biotechscope, 2021; Cuffari, 2019; Precedence, 2022):

- The US AI drug discovery market was estimated to be worth USD 483.7 million in 2022, broken down by therapeutic area.
- In terms of therapeutic area, the infectious diseases segment is expected to expand at the quickest CAGR from 2023 to 2032, while the

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oncology section accounted for 21% of market share in 2022.

- Preclinical testing is expanding more quickly, whereas the medication optimization and repurposing area has a revenue share of around 51% in 2022 based on application.
  With a 56% market share in 2022, North America held the biggest proportion.
  Estimates place the APAC market's growth rate between 2023 and 2032 at an impressive 21.1% CAGR.

Automated systems driven by artificial intelligence will undoubtedly rule the future. Autonomous robotics, programmed robots, and industrial automated machinery has sufficient intelligence to do analysis, forecasting, and decision-making. In the future, we can expect to see AI being used to:

1. Identify new drug targets more quickly and efficiently.
2. Design new molecules that are more effective and less toxic.
3. Predict the efficacy and safety of drugs more accurately.
4. Personalize drug treatment regimens for each patient.

We can also expect to see 3D printing being used to:

1. Produce personalized medications tailored to each patient's specific needs.
2. Create complex dosage forms that are difficult or impossible to produce using traditional methods.
3. Produce small batches of medications, which is ideal for rare diseases or for personalized medicines evolutionary algorithms, to create new molecular structures or optimize existing ones.
4. AI can also help evaluate and rank the generated molecules by estimating their synthetic feasibility, pharmacokinetics, toxicity, and efficacy (Paul et al., 2021) (Fig. 11).

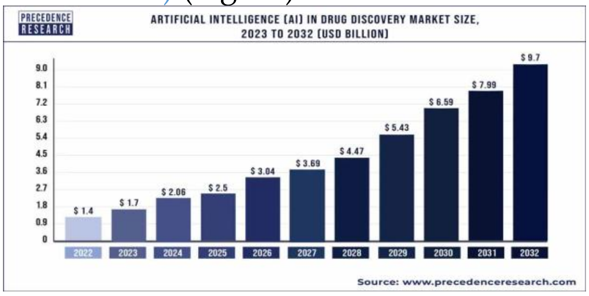

Fig. 11. AI in Drug Discovery Market (Precedence Research, 2022)

4. Conclusion

The pharmaceutical sector is at a turning point. The difficulties of the 21st century cannot be solved by the conventional approaches to drug research and development. Emerging technologies like artificial intelligence (AI), 3D printing, and nanomedicine have the potential to transform the pharmaceutical sector and enhance the lives of millions of people. Future research in the medical area will allow for a closer analysis of artificial intelligence's involvement in several health-related fields. There are several aspects of AI's influence in the pharmaceutical industry that can be discussed. It is a topic worth exploring and debating. With the development of contemporary automation technologies and the explosive expansion of businesses involving AI-powered bots, the pharmaceutical industry is undoubtedly at its pinnacle of development. AI-powered bots will play a significant role in the fields of medicine

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and drug discovery, research, and manufacture.

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