

## Artificial Intelligence (AI) in Pharmacy: An Overview of Innovations

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### Abstract

Artificial Intelligence (AI) emerged as an intervention for data and number-related problems. This breakthrough has led to several technological advancements in virtually all fields from engineering to architecture, education, accounting, business, health, and so on. AI has come a long way in healthcare, having played significant roles in data and information storage and management – such as patient medical histories, medicine stocks, sale records, and so on; automated machines; software and computer applications like diagnostic tools such as MRI radiation technology, CT diagnosis and many more have all been created to aid and simplify healthcare measures. Inarguably, AI has revolutionized healthcare to be more effective and efficient and the pharmacy sector is not left out. During the past few years, a considerable amount of increasing interest in the uses of AI technology has been identified for analyzing as well as interpreting some important fields of pharmacy like drug discovery, dosage form designing, polypharmacology, and hospital pharmacy. Given the growing importance of AI, we wanted to create a comprehensive report which helps every practicing pharmacist understand the biggest breakthroughs which are assisted by the deployment of this field.

**Keywords:** Artificial intelligence, pharmacy, pharmacist

### Introduction

AI is a stream of science related to intelligent machine learning, mainly intelligent computer programs, which provides results in a similar way to the human attention process<sup>[1]</sup>. This process generally comprises obtaining data, developing efficient systems for the uses of obtained data, illustrating definite or approximate conclusions, self-corrections, and adjustments<sup>[2]</sup>. In general, AI is used for analyzing machine learning to imitate the cognitive tasks of individuals<sup>[2, 3]</sup>. AI technology is exercised to perform more accurate analyses as well as to attain useful interpretation<sup>[3]</sup>. In this perspective, various useful statistical models, as well as computational intelligence, are combined in AI technology.

Recently, AI technology becomes a very fundamental part of the industry for useful applications in many technical and research fields. Reflecting on the past 25 years, pharmacy has done a great job of addressing the growing demand for prescriptions, even when faced with pharmacist shortages,

growing operating costs, and lower reimbursements. Pharmacy has also done a great job of leveraging enabling technology automation to improve workflow efficiency and lower operating costs while promoting safety, accuracy, and efficiency in every pharmacy setting. Automated dispensing gives pharmacists more time to engage with a greater volume of patients while also enhancing their health outcomes<sup>[4]</sup>.

The first application of a computer in a pharmacy presumably dates back to the 1980s and since then, computers have been utilized in everything from data collection, retail pharmacy management, clinical research, drug storage, pharmacy education, clinical pharmacy, and lots more, and with the emergence of artificial intelligence, there is no telling just how much the Pharmacy sector will evolve in the long run. There have been several expert systems developed in medicine to assist physicians with medical diagnosis<sup>[5]</sup>. Recently, several programs focusing on drug therapy have been described<sup>[6]</sup>. They guide drug interactions, drug therapy monitoring, and drug formulary selection. There are many aspects of pharmacy that AI can have an impact on and the pharmacists to consider these possibilities because they may someday become a reality in pharmacy practice.

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The purpose of this article was to review topics related to AI. The topics include AI general overview and classification, AI uses in hospitals, the pharmaceutical industry, and retail pharmacies and to create awareness for AI as a component of pharmacy practice in the future, to encourage pharmacists to embrace this advancement, and as much as possible put in the effort to acquire the relevant skills, which will enable pharmacists to contribute towards the much-envisioned development.

### AI general overview

The term AI (also known as machine intelligence) is very commonly confused and used interchangeably with robotics and automation. While robotics is simply the creation of machines that can carry out difficult repetitive tasks, AI refers to the exhibition of human-like behaviors or intelligence by any computer or machine<sup>[7]</sup>. Traditionally, robots were not built to possess these “intelligent capabilities” even though they may be able to move or carry objects independently using a designed program and surface sensors in a process known as automation. AI, in essence, is the field of computer science that specializes in the creation of intelligent machines, developed with the ability to perform tasks that will ordinarily be associated with a human being<sup>[8]</sup>.

AI is frequently applied to the development of digital computers or computer-controlled robots with the capacity to autonomously execute intellectual and cognitive human-like processes. Such intellectual and cognitive processes include learning, reasoning, problem-solving, perception, and language. The form of AI currently in use today is referred to as narrow AI or weak AI because it is only designed to perform narrow tasks like internet search, facial and voice recognition, controlling and driving cars, and so on. However, the long-term goal of the AI community is to have machines that can autonomously outperform humans’ at all cognitive tasks. The AI that involves creating machines that can perform all human cognitive tasks will be the general AI or Strong AI (ADI)<sup>[9]</sup>.

In simple terms, AI refers to the ability of machines and computers to think, act, behave and function as human beings. Familiar examples of AI-controlled systems include Apple’s SIRI (in iPhone)<sup>[10]</sup>, Amazon’s Alexa<sup>[11]</sup>, and the self-driving cars of Google, Mercedes, BMW, and Tesla to name a few<sup>[12]</sup>. The core of AI can be Knowledge Engineering, in which machines are assembled with access to abundant data and information relating to the human world, which enables them to be able to mimic human behavior. Machine Learning is another type of AI, which involves the use of algorithms and statistical models to improve the accuracy of software applications in predicting outcomes without being distinctly programmed. It was established based on the idea that machines can learn from data, identify problems and make decisions with minimum human help or intervention. Applications of machine learning include self-driven Google cars, fraud detection, and online recommendation offers like those on Amazon and Netflix<sup>[13]</sup>.

Machine perception is another aspect of AI and it involves designing and building machines with the ability to use sensory inputs to deduce information about the different aspects of the world. Computer vision is the ability of machines to process visual inputs such as facial information, objects, and gestures<sup>[14]</sup>.

There have been various skepticism, criticism, and myths towards AI mostly concerning safety and the dangers that may be potentiated by the creation of machines that could match human cognitive capabilities. One of the five predictions made by Forbes for AI in 2019<sup>[15]</sup> is that it may become an issue of national politics. Aside from concerns that AIs may be used as weapons for war and mass destruction, certain people have expressed concerns that the creation of AI systems that are smarter than humans, through general AI could be more fatal and be the end of the human race itself. They believe we may not be able to predict how AI systems that are more intelligent than us will behave and that humans may end up being controlled by these super-intelligent machines. Scientists believe most of the safety concerns about future super-intelligent AI systems may be resolved if the “goals” of these machines can be made to align with our own goals<sup>[15]</sup>.

### AI classification

AI can be classified in two different ways<sup>[16, 17]</sup>

- a) according to caliber
- b) according to the presence (See table 1)

**Table 1: Classification of AI**

<b>Based on the caliber</b>	Weak intelligence Artificial narrow intelligence Artificial general intelligence Artificial super intelligence
<b>Based on presence</b>	Type 1 reactive machine Type 2 limited memory system Type 3 is based on the theory of mind Type 4 self-awareness

Based on their caliber, AI system is classified as follows:

- 1. Weak intelligence or Artificial narrow intelligence (ANI):** This system is designed and trained to perform a narrow task, such as facial recognition, driving a car, playing chess, and traffic signaling. E.g.: Apple SIRI virtual personal assistance, tagging in social media.
- 2. Artificial General Intelligence (AGI) or Strong AI:** It is also called Human-Level AI. It can simplify human intellectual abilities. Due to this, when it is exposed to an unfamiliar task, it can find the solution. AGI can perform all the things as humans.
- 3. Artificial Super Intelligence (ASI):** It is brainpower, which is more active than smart humans in drawing, mathematics, space, etc; in every field from science to art. It ranges from the

computer just little than the human to a trillion times smarter than humans.

Arend Hintze<sup>[18]</sup>, an AI scientist classified the AI technology based on its presence and not yet present. They are as follows:

**Type 1:** This type of AI system is called a Reactive machine. E.g. Deep Blue, the IBM chess program which hit the chess champion, Garry Kasparov, in the 1990s. It can identify checkers on the chessboard and can make predictions; it does not have the memory to use past experiences. It was designed for narrow purposes use and is not useful in other situations. Another example is Google's AlphaGo.

**Type 2:** This type of AI system is called a Limited memory system. This system can use past experiences for present and future problems. In autonomous vehicles, some of the decision-making functions are designed by this method only. The recorded observations are used to record the actions happening in the future, such as changing the lanes by car. The observations are not in the memory permanently.

**Type 3:** This type of AI system is called as “theory of mind”. It means that all humans have their thinking, intentions, and desires which impact the decisions they make. This is a non-existent AI.

**Type 4:** These are called self-awareness. The AI systems have a sense of self and consciousness. If the machine has self-awareness, it understands the condition and uses the ideas present in others' brains. This is a non-existing AI.

## Applications of AI

### AI in diagnosis and targeted genomic treatments

There are several applications of AI in hospital-based health care systems<sup>[19, 20]</sup> in organizing dosage forms for individualized patients and selecting suitable or available administration routes or treatment policies.

- **Maintaining of medical records:** Maintenance of the medical records of patients is a complicated task. The collection, storage normalizing, and tracing of data are made easy by implementing the AI system. Google Deep Mind health project<sup>[21]</sup> (developed by Google) assists to excavate the medical records in a short period. Hence, this project is a useful one for better and faster health care. The Moor fields Eye hospital NHS is assisted by this project for the improvement of eye treatment.
- **Treatment plan designing:** The designing of effective treatment plans is possible with the help of AI technology. When any critical condition of a patient arises and the selection of a suitable treatment plan becomes difficult, then the AI system is necessary to control the situation. All the previous data and reports, clinical expertise, etc., are considered in the designing of the treatment plan as suggested by this technology. IBM Watson for Oncology<sup>[22]</sup>, the software as a service, is a cognitive computing decision support system that analyzes patient data against thousands of historical

cases and insights gleaned from working thousands of hours with Memorial Sloan Kettering Cancer Center physicians and provides treatment options to help oncology clinicians make informed decisions. These treatment options are supported by literature curated by Memorial Sloan Kettering, and over 300 medical journals and 200 textbooks, resulting in almost 15 million pages of text<sup>[22]</sup>.

- **Assisting in repetitive tasks:** AI technology also assists in some repetitive tasks, such as examining the X-ray imaging, radiology, ECHO, ECG, etc., for the detection and identification of diseases or disorders. Medical Sieve<sup>[23]</sup> (an algorithm launched by IBM) is a “cognitive assistant” having good analytical and reasoning abilities. A medical start-up is necessary for the improvement of the patient's condition by combining deep learning with medical data. A specialized computer program is available for each body part and used in specific disease conditions. Deep learning can be employed for almost all types of imaging analyses, such as X-ray, CT scan, ECHO, ECG, etc.
- **Health support and medication assistance:** In recent years, the uses of AI technology are recognized as efficient in health support services and also, for medication assistance. Molly<sup>[24]</sup> (a start-up-designed virtual nurse) receives a pleasant voice along with a cordial face. Its aim of it is for helping patients to guide the treatment of patients as well as support them with their chronic conditions during doctor's visits. Ai Cure<sup>[25]</sup> is an app existing in a Smartphone webcam, which monitors patients and assists them to control their conditions. This app is useful to patients with severe medication situations and for patients who participate in clinical trials.
- **Accuracy of medicine:** AI shows a good impact on genomics and genetic development. Deep Genomics<sup>[26]</sup>, an AI system is useful for observing patterns in the genetic information and medical records to identify the mutations and linkages to diseases. This system informs doctors about the events happening within a cell when DNA is altered by genetic variation. An algorithm is designed by the father of the human genome project, Craig Venter<sup>[27]</sup> that gives information on patients' physical characteristics based on their DNA. “Human Longevity” AI technology is useful to identify the exact location of cancer and vascular diseases in their early stage.
  - **Drug creation:** The development or creation of pharmaceuticals takes more than a decade and consumes billions of rupees. “Atomwise”<sup>[28]</sup>, an AI technology that uses supercomputers, is useful to find out the therapies from the database of molecular structure. It hurled a virtual search program for safe and effective therapy for the Ebola virus with the existing drugs. The technology identified two drugs that caused Ebola infection. This analysis was completed within one

day compared to months to years with manual analysis. A Biopharma company in Boston developed big data for the management of patients. It reserves data to find the reasons why some patients survive diseases. They used patients' biological data and AI technology to find out the difference between healthy and disease-friendly atmospheric conditions. It helps in the discovery and design of drugs, healthcare, and problem-solving applications.

- **AI helps people in the health care system:** The "open AI ecosystem"<sup>[29]</sup> was one of the top 10 promising technologies in 2016. It is useful to collect and compare the data from social awareness algorithms. In the healthcare system, vast information is recorded which includes patient medical history and treatment data from childhood to that age. This enormous data can be analyzed by the ecosystems and gives suggestions about the lifestyle and habits of the patient.

- **Healthcare system analysis:** In the healthcare system, if all the data is computerized then retrieval of data is easy. Netherland maintains 97% of invoices in digital format<sup>[30]</sup>, which contain treatment data, physician names, and hospital names. Hence, these can be retrieved easily. Zorgprisma Publiek, a local company analyses the invoices with the help of IBM Watson cloud technology. If any mishap occurs, it recognizes it immediately and takes the correct action. Because of this, it improves and avoids patient hospitalization.

#### AI and development of pharmaceuticals<sup>[31-37]</sup>

Top pharmaceutical companies are collaborating with AI vendors and leveraging AI technology in their manufacturing processes for research and development and overall drug discovery. Reports show nearly 62 percent of healthcare organizations are thinking of investing in AI shortly, and 72 percent of companies believe AI will be crucial to how they do business in the future. To get a better sense of the future of AI in the sector, *Pharma News Intelligence*<sup>[38]</sup> dives into current AI use cases, the best uses for the technology, and the future of AI and machine learning. The McKinsey Global Institute estimates that AI and machine learning in the pharmaceutical industry could generate nearly \$100B annually across the US healthcare system. According to researchers, the use of these technologies improves decision-making, optimizes innovation, improves the efficiency of research/clinical trials, and creates beneficial new tools for physicians, consumers, insurers, and regulators. Top pharmaceutical companies, including Roche, Pfizer, Merck, AstraZeneca, GSK, Sanofi, AbbVie, Bristol-Myers Squibb, and Johnson & Johnson have already collaborated with or acquired AI technologies. In 2018, the Massachusetts Institute of Technology (MIT) partnered with Novartis and Pfizer to transform the process of drug design and manufacturing with its Machine Learning for Pharmaceutical Discovery and Synthesis Consortium<sup>[38]</sup>.

Research works are carried out daily to find new active principles for the currently incurable diseases and conditions; increase the safety profile of already existing drugs; combat drug resistance and minimize therapeutic failure. Hence, there is an increase in the size and variety of biomedical data sets involved in drug design and discovery. This factor and many more contributed to the advancement of AI in the pharmaceutical industry. Today, some companies offer software with much relevance in drug design and data processing, as well as in predicting treatment outcomes.

GNS healthcare<sup>[39]</sup> uses AI machine software known as Reverse Engineering and Forward Simulation (REFS). REFS determines the cause and effect relationships between various types of data, that are unforeseen ordinarily by direct data evaluation. GNS claims that REFS can transfer millions of data points ranging from clinical to genetics, laboratory, imaging, drug, consumer, geographic, pharmacy, mobile, proteomic, and so on. In drug design, a company known as Atomwise developed the first deep learning neural network for structure-based drug design and discovery that they called AtomNet<sup>[40]</sup>. AtomNet makes use of a statistical approach to extract information from millions of experimental affinity measurements and thousands of protein structures to predict the binding properties of small molecules with proteins. By presenting 3-dimensional images of the protein and ligand pair showing channels for carbon, oxygen, nitrogen, and other types of atoms, AtomNet technology enables the pharmaceutical chemists to perform core processes of drug discovery and design like hit discovery, lead optimization, and prediction of toxicity with high precision and accuracy in weeks as against years.

Insilico Medicine<sup>[41, 42]</sup> announced an AI project by the company called Pharm AI. Insilico Medicine claims they applied Generative Adversarial Networks (GAN) and reinforcement learning algorithms. The GAN is a type of generative model that can generate samples and also learn from training samples. They are made up of two neural networks, the generator, and the discriminator. The relationship between the generator and the discriminator is referred to as "adversarial". The generator tries to create and learns to create new samples and sends them to the discriminator, which classifies the sample as real or fake where real denotes the examples that belong to the data set, and the examples generated by the generator are denoted "fake". Through continuous training, the generator begins to create samples that are similar to the real ones while the discriminator gets better at the identification process. With Pharm AI, through GAN and reinforcement learning, Insilico Medicine claims that it can generate new molecular structures and ideate the biological origin of a disease.

#### AI in pharmacy practice in hospital and community pharmacies

Machine learning models allow e-mails to be personalized at a speed and accuracy greater than that of any human being. Chatbots<sup>[43]</sup> can be used to increase the efficiency of service

delivery. Chatbots are capable of mimicking interactions between customers and customer care of sale staffs. Chatbots are capable of automatically resolving customer complaints and queries and the difficult questions are transferred to human staff. In retail pharmacy, this principle can be applied. The chatbots can be programmed to mimic pharmacist-patient interaction.

Walgreen<sup>[44]</sup> made a partnership with Medline, a telehealth firm to create an avenue to help patients interact with healthcare professionals through video chat. AI can also be useful in inventory management. As a retail pharmacist, imagine being able to predict what your patients will need in the nearest future, stocking them, and using personalized software to deliver e-mails to remind the patient of drug needs. With the use of AI-powered data analytics, a patient's future drug purchase can be predicted. Predicting the patient's drug purchase through AI will help the pharmacist to make proper stock procurement decisions.

Although, there are existing inventory management software and application that are used in retail pharmacy stock management like Mckessons; Liberty; Winpharm; PrimeRx; and WinRx, not all of them utilize AI or machine learning. For example, an AI company, Blue Yonder developed software for Otto group<sup>[45]</sup>, a German online and catalog retailer. This software can predict with 90% accuracy what will be sold by Otto in 30 days. This reduced the delivery schedule for purchased products from one week or more to one of two days by enabling direct delivery of the product from the supplier to the consumer without having to pass through the warehouse.

Intending to improve the safety of patients, the University of California San Francisco (UCSF) Medical Center uses robotic technology for the preparation and tracking of medications. According to them, the technology has prepared 3, 50, 000 medication doses without any error. The robot has proved to be far better than humans both in size as well as its ability to deliver accurate medications. The abilities of the robotic technology include the preparation of oral as well as injectable medicines which include toxic chemotherapy drugs. This has given the freedom to the pharmacists and nurses of UCSF so that they can utilize their expertise by focusing on direct patient care and working with the physicians. Within the automated system of the pharmacy, the computers first receive medication orders electronically from the physicians and pharmacists of UCSF. After this, individual doses of pills are picked, packaged, and dispensed by the robotics. This is followed by machines assembling the doses onto a bar-coded plastic ring. The thin plastic ring contains all medications that have to take by a patient within a period of 12h. Adding to the capabilities of the automated system is their ability to prepare sterile preparations that are meant for chemotherapy along with filling intravascular syringes with the right medications<sup>[46]</sup>.

## Discussion

The primary aim of health-related AI applications is to analyze relationships between prevention or treatment techniques and patient outcomes. AI programs have been developed and applied to practices such as diagnosis processes, treatment protocol development<sup>[47]</sup>, drug development<sup>[1]</sup>, personalized medicine<sup>[48]</sup>, and patient monitoring and care<sup>[49]</sup>, among others. As the quality of care offered for patients continues to grow in prominence, here are some ways pharmacies can leverage the continued technology explosion to impact value-based outcomes. As the most accessible and affordable healthcare stakeholder, pharmacies can become health management centers instead of only medication fulfillment locations. Technology can help provide more personalized healthcare offerings including advice, guidance, and an expanded suite of services (e.g., immunizations, screenings, MTM, disease state management). Health trackers and wearable will be able to provide real-time capture of data that can enable pharmacy to follow up with at-risk patients on their conditions and monitor their quality of improvement<sup>[50]</sup>.

AI can be of real help in analyzing data and presenting results that would support decision making, saving human effort, time, and money, and thus helps save lives. Medical and technological advancements that have helped the healthcare-related development of AI include the overall evolution of computers, resulting in faster data collection and more powerful data processing, Growth in the availability of health-related data from personal and healthcare-related devices and records, and the development of pharmacogenomics and gene databases, Expansion and industry adoption of electronic health records and natural language processing and other advancements in computing that have enabled machines to replicate human certain processes<sup>[51]</sup>.

In the physician space, AI from technology companies like Microsoft is breaking into the healthcare industry by assisting doctors in finding the right treatments among the many options for cancer. Capturing data from various databases relating to the condition, AI is helping physicians identify and choose the right drugs for the right patients<sup>[52, 53]</sup>. In the pharma space, AI is working with researchers to support the decision-making processes for existing drugs and expanded treatments for other conditions, as well as expediting the clinical trials process by finding the right patients from several data sources <sup>[1, 54, 55]</sup>. Pharma is even working to predict with certain accuracy when and where epidemic outbreaks might occur, using AI learning based on a history of previous outbreaks and other media sources.

In the hospital space, AI is being used to prevent medical errors and reduce hospital readmissions. By analyzing patient data from medical and medication errors, readmission root causes, and other internal and external databases, AI will one day identify and prevent high-risk patients from developing complications, and provide prospective care guidance, and diagnostic support, among many other clinical applications.

Additionally, AI will be useful in workflow optimization and efficiency, helping eliminate redundancy in cost from duplicate or unnecessary procedures<sup>[56, 57]</sup>.

In pharmacy today, we already have an early form of AI in place. It's called our pharmacy management system, housing patient utilization, and drug data, as well as potentially identifying drug-related problems through clinical decision support screening. The next generation in pharmacy technology is the introduction of a technology-based information expert system to identify timely drug-related problems based on patient data captured from the pharmacy system and other external data systems. Consistent with workflow robotics, this would leave less of the work on the pharmacist to shoulder the responsibility of identifying serious drug-related problems<sup>[58, 59]</sup>.

### Implications for pharmacists and their practice

AI can strongly influence and shift pharmacists' focus from the dispensing of medications toward providing a broader range of patient-care services. The pharmacist can leverage AI to help people get the most from their medicines and keep them healthier. Most importantly, AI provides pharmacy an opportunity for more collaboration across many different entities serving the same patient. For the patient, in addition to potentially better healthcare services offered by their professionals, AI may be a useful tool for providing guidance on how and where to obtain the most cost-effective healthcare and how best to communicate with healthcare professionals; optimizing the value of data from wearable; providing everyday lifestyle guidance; integrating diet and exercise; and supporting treatment compliance and adherence.

### Concluding comments

AI involves the combination of human knowledge and resources with Artificial Intelligence. As research into AI continues, with many interesting applications of it in progress, one may consider it a necessary evil even for those that see it as an enemy. Therefore, it is strongly recommended that pharmacists should acquire the relevant hard skills that promote AI augmentation. Education about and exposure to AI is necessary throughout all domains of pharmacy practice. Pharmacy students should be introduced to the essentials of data science and fundamentals of AI through a health informatics curriculum during their PharmD education. Pharmacists must also be allowed to develop an understanding of AI through continuing education. Data science courses or pharmacy residencies with a focus on AI topics should be made available for pharmacists seeking more hands-on involvement in AI development, governance, and use. As these technologies rapidly evolve, the pharmacy education system must remain agile to ensure our profession is equipped to steward these transformations of care.

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### List of abbreviations:

<b>MRI</b>	Magnetic resonance imaging
<b>CT</b>	Computerized tomography
<b>ECHO</b>	Echocardiogram
<b>ECG</b>	Electrocardiogram
<b>DNA</b>	Deoxyribonucleic acid
<b>NHS</b>	National health services
<b>GSK</b>	GlaxoSmithKline
<b>GNS</b>	Gene network sciences
<b>MTM</b>	Medication therapy management

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