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The Evolution of Pharmacy: From Traditional Remedies to Modern Pharmaceuticals

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Abstract

Pharmacy is an ancient science which developed parallel with the medicine from the very beginning of human civilization. The roots of pharmacy started to the very beginning of human civilization (Zunic et al., 2017). People collected the medicinal herbs in order to alleviate their health problems. The first written records about the medicinal plants are from Sumerians, Babylonians and Egyptians. The scientific foundations of the pharmacy were set up in antique period by the books of Dioskurides and Galen. With the books of Dioskurides medicine and pharmacy entered in the Roman Empire and later on in Greece. The more important progress in the pharmacy was done in the Arab countries. The translation of Greek written heritage into the Arabic language preserved the Greek literature from the extinction. Because of the numerous Arabic translations of the Greek books, the Arab countries became the center of knowledge during the Dark Ages in Europe. In the second half of the 14th century many Arabic books were translated into Latin which helped to the Renaissance of Europe. The beginning of the New Age was marked by the invention of the printing press in 1440. The first printed book in the world was the Holy Bible. The first printed book in the medicine and pharmacy was the Latin translation of the Materia medica by Dioskurides. Europe was hit by the Plague which killed almost one-third of the population. The all hygiene measures, including the establishment of the public baths were abolished by the Church. The book of Galen on the hygiene was ignored. The separation of doctors and pharmacists occurred in 1240.

Keywords: Pharmacy, the science of drugs, is derived from the Greek word “pharmakon,” meaning remedy. The roots of pharmacy reach the very beginning of human civilization (Zunic et al., 2017). Petrolatum, a medicinal mineral substance, was used in ancient Babylon 4,000 years ago. Ancient Chinese priests used herbs for healing as early as 2,700 B.C. Egyptian hieroglyphics reveal prescriptions for over 700 medicines. The Ebers Papyrus from the time of Pharaohs contains over 800 remedies. Indian Ayurvedic texts date back to 1,000

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B.C. Greek Dioscorides' "De Materia Medica" served as the basis for Western pharmacology for over 1,500 years. The effort to preserve and pass on knowledge of medicinal herbs led to the writing of many recipe books, the forerunners of today's pharmacopeias. Recipes for simple medicines, mixtures of several ingredients, and antidotes were recorded. The oldest written European recipe is from 1st Century AD, while the earliest pharmacopeia is from 1240 A.D. in France. The medieval Arabic translation of Greek writings significantly advanced pharmacotherapy. The entire Mediterranean region, including Spain and southern France, developed pharmacotherapy under the influence of Arabic and Greek heritage. The first pharmacy in Europe was opened in 1190 in Italy. Medieval monasteries were centers of learning and knowledge preservation, where monks copied ancient Greek and Roman texts. The aspiration to classify medicinal herbs led to large herbariums, early pharmacognosy beginnings. Descriptions of plants in herbariums and later in incunabula led to the development of botany and pharmacognosy. The first pharmacognosy department opened in Padua in 1533. In the first half of the 16th Century, over 75 European herbariums were published, most in Italy.

1. Introduction

The roots of pharmacy started with the collection of medicinal herbs to alleviate health problems. Knowledge was transmitted verbally or through simple drawings until the development of writing. In the antique period, the scientific foundations of pharmacy were set up by Dioskurides, who described 600 herbal drugs and Galen, who invented the basis of preparation methods with his 120 pharmaceutical forms (Zunic et al., 2017). With the decline of the antique civilization came the oblivion of pharmacy and herbal remedies, but the knowledge was preserved by the Arabs. With the Arab conquests, Greek culture and medicine spread, and with the translation of antique texts into Arabic, pharmacy flourished. At the beginning of the mid-century, with the rewriting of ancient literature and new discoveries, pharmacy entered into the new epoch. The most famous book of this time is the "Confessions" by the Arab poet and physician Abul Extremely regarded in the West were the works of the pharmacist and physician Rhazes, who discovered alcohol and used it to prepare elixirs. With Avicena's "Canon of Medicine", which contained a description of 800 drugs, the knowledge of pharmacy and healing reached its peak. In Europe, pharmacy literature was scarce until the 12th century. The first guidance for drug preparation was the translation of Garderobum from the Latin by Peter of Spain. One of the greatest European herbalists was Hildegard von Bingen, who described 200 medicinal plants. A significant role in the development of pharmacy was the preparation of the ancient and Arabic texts at the Salerno school. In the 13th century, the sudden development of pharmacy literature prepared in the school in Montpellier, the center of Latin medicine and pharmacy literature, was of great importance. In 1240, the separation of the doctors and the pharmacists occurred in Paris, and there was a compilation of the Galen's pharmaceutical regulations in the Latin West. The first

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pharmacy opened in 1180 in Montpellier and at the beginning of the 13th century in Paris. During the 14th and 15th centuries, the pharmaceutical art in the West reached its peak, or the golden epoch of pharmacy literature. In Munich, there was a compilation of Arabic and Latino texts with the vastum z medicinalibus simplicibus, the oldest Latin pharmacopoeia.

2. Traditional Healing Practices

Pharmacy, or the preparation and dispensing of medicinal drugs, has existed in various forms throughout human history. Archaeological findings in ancient Mesopotamia indicate that the Sumerians had developed herbal remedies as early as 3000 B.C. (Kuchta & Cameron, 2021). Similar evidence of traditional healing practices exists in ancient China, India, and Egypt. Over time, these traditional remedies formed the basis of modern pharmaceuticals, which grew out of the scientific examination and refinement of herbal cures. In general, traditional remedies consist of crushed herbs mixed with other substances, such as oils, fats, honey, salt, or alcohol, to enhance the delivery or effectiveness of the medicinal ingredients. In addition to these herbal preparations, many ancient civilisations recognised the importance of elemental and chemical remedies. For example, the Sumerians treated ailments using mineral salts, and the Egyptians developed elaborate pharmaceutical practices using natural minerals such as natron and malachite. These practices persisted in the ancient civilisations that succeeded them, most notably those of Greece and Rome. Throughout the Middle Ages, the pharmaceutical knowledge of these classical societies was preserved by Islamic cultures, until it was reintroduced to Western Europe during the Renaissance. Together with the recovery of classical learning, this laid the foundation for the rise of modern chemistry and the scientific approach to elemental and chemical remedies.

2.1. Herbal Medicine

The primitive man’s curiosity to find out the edible and poisonous things in nature resulted in the discovery of herbal drugs. His habit of trial and error to pick up the eatables found in nature developed a sense of observation. The first step towards the evolution of science was observation. His observation must have been directed towards the effect of particular edible things on health. Likewise, he must have been observing the effect of some poisonous things on health. Observations on the feelings of ailing people must have induced him to think of the things which could restore good health to the diseased. This thinking capacity paved the way to the discovery of herbal drugs (Zunic et al., 2017).

The development of drug information is considered as one of the significant steps towards the evolution of pharmacy. The effort to maintain the knowledge of drug information discovered by chance or observation might have induced some people to note it down in writing. The effort to maintain knowledge of medicinal herbs and its practical application has led to the writing of a large number of recipes books, while the aspiration to classify medicinal herbs

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has led to a large number of herbaria. A herbaria is a collection of preserved plant specimens along with details on their habit, habitat, location, and date of collection. The knowledge and description of plants in herbaria made it accessible to many and herbarium specimens assisted in the development of taxonomy. Descriptions of plants in herbaria and later in incunabula lead to the development of pharmacognosy.

2.2. Acupuncture and Acupressure

Acupuncture involves the insertion of needles into specific body points while acupressure uses manual finger pressure. Both are based on an energy network system called meridians affecting the flow of qi or vital energy. Contemporary research has largely focused on acupuncture and recently included laser acupuncture. Acupressure is also called acupoint massage or shiatsu in Japan. A combination of acupuncture and continuous finger pressure was found to improve hand functions of stroke patients. Acupressure was effective in postoperative patients with nausea as well as in relieving anxiety, depression, and sleep disorders in pregnant women. Laser acupoint stimulation was effective against hemorrhoid pain during pregnancy (Litscher, 2012).

Acupuncture and moxibustion are two important components of traditional Chinese medicine. The former involves the stimulation of specific body points with needles while the latter involves the application of heat to specific body points through burning moxa. Acupuncture and moxibustion therapy has been used for thousands of years and more than one hundred million people receive acupuncture worldwide annually. Acupuncture and moxibustion manipulate meridians, qi, and blood to treat diseases. Research into acupuncture and moxibustion is important for further developing this medical tool and ensuring its safe use. Acupuncture and moxibustion historical literature clarifies the origin and development of acupuncture (Run-Ming, 1985).

2.3. Homeopathy

Homeopathy belongs to the category of “alternative medicine.” A multitude of therapeutic methods—some fairly extravagant—fall under this label, which enjoys great popularity with patients (Borkens et al., 2023). For supporters and exponents of these alternative methods, mainstream medicine is dogmatic, inflexible, and blinded by commercial interests—allegedly at the expense of the health of humanity. For critics, such as scientists and proponents of evidence-based medicine, alternative medicine is nonsense or worse: dangerous quackery.

The controversy surrounding alternative medicine is rooted in a basic pattern of human behavior, learning, and understanding. Until the scientific method slowly began to spread in the seventeenth century, all therapeutic methods—from magic to folk remedies and to herbalism practiced by monks—were based on concepts on which the scientific method could not have any impact (Bellavite et al., 2005). The emergence of scientific medicine from

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curiosity about the functioning of the organism and from the desire to have an effective remedy was accompanied by the disappearance of many pre-scientific methods applied by lay people. However, some therapeutic methods—including homeopathy—survived this dawning epoch of science and stuck to the pre-scientific notions.

3. The Birth of Modern Pharmacy

The roots of pharmacy started to the very beginning of human civilization, when people collected various medicinal herbs. Anatomy and the knowledge of therapeutic properties of herbs had ancient Egyptians who applied it in the practice, but this knowledge was well-kept secret (Zunic et al., 2017). The scientific foundations of pharmacy were set up in the antique period by the books of Dioskurides and Galen. Dioskurides was a physician in the army of Nero, and he wrote five books of Materia Medica. Dioskurides' book represented a review of knowledge in botany and pharmacology at that time. It was translated into many languages and had a great influence on the development of pharmacy. Galen was a physician in a gladiator hospital in Pergamum, and later he became a physician to the emperors in Rome. Galen's books were a review of his own experience in the preparation of medicinal drugs. Based on his knowledge, he introduced many forms of drugs that are still in use today. At the very beginning, drugs were prepared by the same people who prescribed them. In 1240, for the first time in history, came the separation of doctors and pharmacists, and thus the beginning of the pharmacy as an independent profession. At that time, in Munchen, the first pharmacy called "Brotze" was opened. The apothecary was also a doctor and the pharmacy was part of the hospital. In 1251, in Florence, the first pharmaceutical legislation was passed. In the beginning of the 13th century, the first pharmacy was opened in Paris. At that time, Paris was the world center of education with the oldest university. Everything that was done in Paris was a model for imitating other cities.

3.1. Emergence of Apothecaries

The roots of pharmacy started with people collecting medicinal herbs to alleviate health problems. Knowledge of plants with healing powers was passed from generation to generation. The scientific foundations of pharmacy were set up in the antique period by the books of Dioskurides and Galen. Dioskurides wrote a five-volume book «On the Materia Medica» about 60 plants that could treat many health problems. This book, along with Galen's writings, was used as a textbook for pharmacology for the following 1500 years. In the Middle Ages, monks cherished the knowledge of medicinal herbs. They cultivated healing plants in monastery gardens and prepared remedies from them. The first written recipes for remedies were found in a monastic book from the 9th century. In the 11th century, the first public gardens of healing herbs were opened in Italy. In the 12th century, the knowledge of healing herbs was brought to the West by the Moors. In medieval towns, apothecaries (from Greek: apotheca-storage) began to open, which sold medicinal herbs and

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prepared remedies from them. In 1240, the separation of doctors and pharmacists occurred. The law forbade doctors to prepare remedies and ordered them to take ready-made remedies from apothecaries. This law initiated numerous lawsuits between doctors and apothecaries over the right to prepare remedies. The first pharmacy opened in the early 13th century. Pharmacies spread throughout Europe in the 14th century (Zunic et al., 2017).

3.2. Scientific Revolution and the Age of Enlightenment

With the renaissance and exploration of the world, new raw materials arrived in Europe from Asian countries. The development of pharmacy was most evident in Germany, where apothecaries had their own guilds. The first pharmacopoeia in Europe was printed in Nuremberg in 1542. The curative and poisonous properties of plants were widely researched during the 16th century, and the foundations of medicinal botany were set. Studies of many European plants were carried out, with herbalists describing their medicinal use (Zunic et al., 2017).

With the scientific revolution and the age of enlightenment, pharmacy became an independent science. A discovery of the greatest importance for pharmacy was the invention of the microscope, which opened a new phase in the study of plants and plant extracts. A special place in the history of pharmacy in the 18th century belongs to the Liburnia region. There were many apothecaries in Zadar, Šibenik, and Trogir, who had their own pharmacy and pharmacopoeia. The Liburnia region was rich in medicinal plants, and many of them are still used today. The accession of the Liburnia region to the Habsburg Monarchy led to significant changes in the development of pharmacy.

4. Key Milestones in Pharmaceutical Development

Throughout history, public health has always been an imperative issue for society. The earliest records of health care providers around 4000 years ago, were physicians employed by rulers, who treated nobles and royalty. As societies evolved, so did the need for more organized health care systems. The foundation of countries' health care systems came with the establishment of hospitals. The first hospitals were built in the Roman Empire, providing free health care to all citizens, which continued during the Middle Ages, when Christianity spread across Europe. With the establishment of monasteries, learned monks took up the role of physicians, caring for the sick and the needy. During the Middle Ages in Europe, a period of stagnation for science and medicine, the knowledge of the ancient Romans and Greeks was preserved in the Islamic world. The establishment of the first pharmacy in 754 in Baghdad, for the first time in history separation of doctors and pharmacists in 1240 in Moorish Spain, and the translation of Galen's and Dioskurides' works into Latin in the 12th century, significantly contributed to the Renaissance and shaping modern pharmacy (Zunic et al., 2017).

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4.1. Isolation of Active Ingredients

The isolation of active ingredients from plants was a decisive step in the scientific maturation of pharmacy. Sydenham's success with the isolation of quinine laid the foundation for modern pharmacy, although it took another 205 years until the success in isolating morphine (Zunic et al., 2017). It was not until the 19th century that pharmacy began to be viewed as an independent branch of medicine. It became more scientifically founded, i.e., the ether extraction of spigol, the active principle of cooper's mouse poison, in 1825, marks the beginning of modern pharmaceutical chemistry. It is very often forgotten that pharmacy pursued the basic scientific disciplines, i.e., pharmacy guilds employed naturalists, mathematicians and astronomers. With the great geographical discoveries in the 15th century new plants with drug potential were brought to Europe, i.e., cinchona bark - from which quinine for treating malaria was later isolated. Cordus' herbal with drug plants from newly discovered lands is an important turning point in the development of pharmacy and pharmaceutics. The first public pharmacy was opened in 1221 in Baghdad, the Arabic capital (in Europe the first one was opened in 1140 in Palermo). Under the Arabs pharmacy reaches its greatest development in the Middle Ages, i.e., Al-Razi - 200 drug monographs - the forerunner of pharmacopoeia, discoverer of alcohol. The first pharmaceutical regulation was laid down in 1240 by Emperor Frederick II in the document "De arte venandi cum avibus", which prescribed that one apothecary from each cathedral town should be employed.

4.2. Industrialization of Pharmaceutical Production

During the 19th century, attempts at the industrialisation of the ayurvedic system were initiated though with varied levels of success in different regions. The growth of large-scale production units is indicative of this proto-industrialisation phase. Unlike in Bengal, where mass production was the result of the entry of capital, in some regions, such initiatives were taken by physicians themselves. This was especially the case of kerala, where, after 1846, the ashtavaidyas of vaidyaratnam family started large-scale production of ayurvedic drugs. With the introduction of steam engines in 1874, the Oushadhalayam became the first mechanised factory in the kerala region. Though initially the drugs were prepared exclusively for home consumption, from the 1880s the factory began to market drugs outside kerala — a trend which the Kottakkal ashtavaidyas followed later in 1908 (S. Harilal, 2008). In Travancore, from the 1870s, the East India Company patronised the establishment of ayurvedic factories. The first factory was established at Kanattukara by Madhava Sastrikal in 1820. By the end of the nineteenth century, a number of ayurvedic factories were opened at various places, the most well-known being the Oushadhalaya at Thiruvalla, established by Vaidyadhiraja Ramakrishna Panicker in 1886. The incapacity of the modern system to cater to the health care needs of a large number of villages helped the indigenous systems to remain significant. Still, the ayurvedic community did feel the necessity to modernise the systems. The

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experiments at kochi represented some attempts to catch up with the modern professionalisation. At other levels, the experiments with large-scale production systems might be viewed as efforts to professionalise the ayurvedic system.

5. Regulation and Standardization of Pharmaceuticals

Quality standards for pharmaceuticals are essential to protect public health but are generally a recent development (Dukes, 2006). For new medicines developed by the pharmaceutical industry, necessary quality standards are created by the originating company and assessed by the Drug Regulatory Authority of each country where marketing approval is sought. Only in later years, as patents expire, is a public pharmacopoeia monograph likely to be issued for the drug, often developed in collaboration with the manufacturer. For herbal medicines that are claimed to be traditional, the burden of proof is almost the opposite. A public pharmacopoeia monograph may be sought for the product, but usually only after the drug has been the subject of legal challenge. In the interim, companies rely on the public's ignorance of what traditional medicine involves, and of the fact that pharmacopoeia standards provide only safeguards for certain basic medicinal substances. Finished products are now increasingly included in many national pharmacopoeia volumes and are finding their way into the International Pharmacopoeia published by WHO. Procedures to license and inspect pharmaceutical factories have existed since the nineteenth century, but standards have greatly developed since the introduction of Good Manufacturing Practice (GMP). The GMP concept arose after 1963 when the United States FDA first introduced regulations for manufacturing, packaging, and storing medicines in its code of Federal Regulations. Since then, extensive GMP rules have been developed (Imran et al., 2013). The Council of Europe began work on its GMP publication in 1964, with a first edition in 1971. Currently this provides guidelines for medicinal products, herbal medicines, and radiopharmaceuticals. WHO's GMP guidelines were first published in 1968, with a revised edition in 1975, and were intended for developing countries. GMP guidelines are also available for herbal medicines, and radiopharmaceuticals. Specific GMP provisions have been published for blood products, biotechnological products, and starting materials for API manufacturing. The GMP principles have been in various legal instruments since 1978, culminating in 2003 in the new Directive on Good Manufacturing Practice, which repealed former directives.

5.1. Formation of Regulatory Bodies

The formation of regulatory bodies was an important development in the evolution of pharmacy. As pharmaceutical companies began to produce a wider variety of drugs, there was a need to ensure the safety and efficacy of these drugs. Regulatory bodies were established to set and enforce standards for drug development and testing. At first, these regulatory bodies were often seen as a hindrance to progress. Many pharmaceutical companies argued that regulations stifled innovation and made it difficult to bring new drugs

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to market. However, over time, most companies came to accept the need for regulations. Indeed, by the late twentieth century, many firms regarded the approval of a drug by regulatory authorities as a badge of quality (Abraham, 2002). The story of drug regulation is not only about the wider regulation of commerce and its attendant problems. It is also about efforts to protect public health and safety through the regulation of drugs and related practices. The central legislation that regulates the import, manufacture, distribution and sale of drugs and cosmetics in India is the Drugs and Cosmetics Act, 1940. This Act was enacted during the British Rule in India. Prior to 1940, there were two separate legislations, the Dangerous Drugs Act, 1930 and the Indian Purchase of Drugs Act, 1938, to regulate drugs (Imran et al., 2013).

5.2. Development of Drug Approval Processes

As the pharmaceutical industry grew, so did the need for regulation. In the United States, the Pure Food and Drug Act of 1906 prohibited the interstate commerce of misbranded and adulterated foods and drugs. The Food and Drug Administration (FDA), initially called the Bureau of Chemistry, was charged with enforcing the new law (Seoane-Vazquez et al., 2024). The 1906 Act gave the FDA the power to oversee drug labeling but not to evaluate the safety or effectiveness of drugs before they were marketed.

Given the public and private resources expended in developing new therapies, it is important to understand the safety and efficacy evidence required for the development and approval of pharmaceutical products. During the period 1980–2022, there was a substantial increase in the number of marketing approvals of new drug products, particularly biologics, with the majority being antineoplastic and immunomodulating agents. A significant proportion of the newly approved drugs were granted approval through designations and expedited review procedures, which do not require the demonstration of addressing unmet medical needs or providing superior patient benefits compared to existing marketed alternatives.

Throughout the study period, the legislative objective of bringing more drugs to the US market more quickly has been accomplished; however, the regulatory basis for the quality of evidence for approval has lessened and not kept pace with the speed of approvals. Whether the new drugs approved via expedited pathways have enhanced patient outcomes or provided therapeutic advantages for unmet medical needs once introduced into clinical practice warrants further research.

6. Pharmacy in the Digital Age

Pharmacy services have been typically conducted within local establishments where pharmacists and patients could interact face-to-face. Because of their knowledge of drugs and medicines, pharmacists have traditionally played a vital role in improving public health by providing patient education. For many decades, pharmacy services have focused on paper-

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based procedures. The advent of the new digital technologies largely ignored in the pharmacy sector, and the services have not changed much until now. However, the growing need for digital transformation is clear evidence of the drive for a more effective, transparent, and patient-centered healthcare (Almeman, 2024). Breakthroughs in mobile communications, cloud computing, advanced analytics, and the Internet of Things (IoT) have reshaped various sectors of the economy; these breakthroughs in technology and the service delivery have also great potential to improve patient care and pharmacy services.

A number of critical forces are fueling this digital transformation in the pharmacy sector. The frustration because of a lack of transparency and inefficiency in the design, development, and manufacture of medications has been driving the demand for greater transparency and efficiency. Other key drivers include a growing desire for patient-centered services, cost-effectiveness, improved patient care, and appropriate service delivery. Digital technology is propelling a massive worldwide shift in the pharmacy sector undertaken with the intention of enhancing productivity, efficiency, and flexibility in the delivery of care activities. In the implementation of pharmacy services, digital technologies such as automation, computerization, and robotics have become critically essential for reducing costs and improving treatment delivery.

6.1. Telepharmacy and Online Pharmacies

The telepharmacy program at CVS Pharmacy allows a pharmacist to remotely counsel and verify prescriptions for up to ten locations, primarily serving underprivileged communities without on-site pharmacists. E-prescribing software enhances prescription accuracy, while digital health apps help patients manage conditions like asthma. CVS is investigating blockchain technology for supply chain management, ensuring data integrity and security. Moodle enables continuous learning, networking, and discussion topic creation, while CPD platforms offer training program access. Telehealth and online health services provide easier access to health services, particularly for the elderly or disabled. Similar opportunities in pharmacy practice include telepharmacy services, which use technology for remote pharmacist and patient communication. Online pharmacies, a digital transformation, allow patients to order prescription or over-the-counter medications online, requiring a valid prescription. In the US, millions rely on online pharmacies for medication orders. The COVID-19 pandemic accelerated this digital shift globally. Recent studies reveal increasing consumer trust in online medication purchases from licensed pharmacies. Despite concerns about illegal online pharmacies, consumer behavior is shifting towards these platforms as reliance increases, indicating that perceived benefits outweigh perceived risks (Almeman, 2024). This change in behavior highlights the growing importance of credibility for online pharmacies, necessitating the implementation of quality assurance system elements, particularly for low and middle-income countries.

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6.2. Artificial Intelligence in Drug Discovery

The discovery and development of new medications involve a wide variety of technologies and expertise, and are generally termed as drug discovery. It is one of the most time-consuming and expensive tasks, taking approximately 10–15 years and around 2.6 billion USD to discover one new drug (Chen et al., 2023). Traditionally, the biological method-based high-throughput screening (HTS) is employed to search for new bioactive compounds from natural product libraries or synthetic chemical libraries. To obtain a drug candidate from a hit compound, a series of optimization processes are required to improve the hit compound's efficacy, selectivity, and druggability. The iterative design-synthesis-bioassay cycle generally involves experimental data annotation, which is time-consuming, and data mining, which is usually done by using quantitative structure–activity relationship (QSAR) models. However, the low-efficacy and high-cost characteristics of conventional HTS and optimization methods have become the hurdles of drug discovery. Therefore, the necessity of high-throughput biology and chemistry techniques and the development of new data analysis methods to deal with such a time-consuming and expensive task has long been emphasized.

With the ongoing technology advancement in biological data generation, biological data have rapidly accumulated in public databases. The availability of multi-omics data, such as genome sequencing data, transcriptome data, proteome data, metabolome data, and protein–ligand interaction data, has provided great opportunities for the implementation of data mining methods in pharmaceuticals. In addition, the revolution in high-performance computer hardware, such as graphic processing units (GPUs), cloud computing, and supercomputers, has enabled high-throughput molecular dynamics (MD) simulations on millions of biomolecules or chemical compounds, which can generate vast amounts of simulated data. Due to the "large data, low knowledge" characteristic in drug discovery, data-driven knowledge discovery methods are in great demand. Artificial intelligence (AI) techniques, particularly machine learning (ML) methods, are able to discover knowledge from data and have been employed in diverse disciplines, such as astronomy, geography, climate change, human health, and systems biology. The successful application of AI techniques, particularly to biological data analysis, has attracted the attention of the pharmaceutical industry. As a result, AI technique implementation into drug discovery processes, including compound activity prediction, ADMET liability prediction, and drug design, has recently become a hot topic in both academia and industry.

7. Challenges and Opportunities in Modern Pharmacy

The profession of pharmacy is at a crossroads, facing challenges and opportunities shaped by societal needs, technological advancements, and environmental concerns. Addressing public health needs, such as advocate for patients and preventive interventions, is crucial as diverse roles in employment emerge. The appropriate use, development, and evaluation of medicines

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are central to pharmacy (Papadopoulos et al., 2021). However, public understanding of what pharmacists contribute is minimal, hindering harnessing their full potential. Increasing urban population pressure necessitates a focus on desired societal roles for pharmacists, ensuring adherence to global and local desirable roles while maintaining the profession's viability.

A 2030 vision considers what society expects from pharmacy and ensures development paths for desirable roles. It aims to identify key challenges and opportunities for pharmacy's future, articulating needed developments to achieve a desired future and emphasizing public understanding of pharmacy contributions. Focusing on significant challenges and opportunities for the profession as a whole over the next 10 to 20 years, commentators from various countries examine local contexts of worldwide changes affecting pharmacy. These include population aging, healthcare access equality, progress towards universal health coverage, health data digitization and analytics, emerging health technologies, and efforts to mitigate climate change.

7.1. Drug Resistance and Antimicrobial Stewardship

As drug resistance grows, discovery of new antibiotics must be balanced with stewardship of existing drugs. Rediscovered routine use in non-human mammals of a pre-antibiotic era ecological balance curbs resistance in wild and livestock populations. Feedbacks emerging from cross-species transmission of antibiotic resistant bacteria complicate pro-development conservation. Nanobacterial medicinals evolved on the coattails of antibiotics in historical pre-experimental medical practices shaped by global politics, religion, and culture. Modern medicine misconceives nanobacterial medicinals as placebos even as the care, rites, and symbols of efficacy surrounding their use induce patient responses comparable to antibiotics and antivirals. Conveys a microscopic view of the evolution of drug resistance to antibiotics and other antimicrobials and its ecological balance beyond current pro-development conservations (Woon & Fisher, 2016).

Multidrug resistance (MDR) in microorganisms continues to be a global concern, particularly for pathogenic bacteria resistant to antibiotics, threatening the efficacy of current treatments. To address this crisis, the World Health Organization has prioritized the discovery and development of new antimicrobial agents, urging pharmaceutical companies to create novel classes of antimicrobials. However, progress has stalled, leading to calls for alternative therapeutic approaches against MDR bacteria. A rational strategy to overcome antibiotic resistance is to simultaneously inhibit a bacterium's resistance mechanisms while employing antibiotics against it. This review discusses the significance, threats, and challenges posed by MDR microorganisms, as well as success stories of natural product-derived compounds from plants investigated as modulators of MDR in microorganisms, which may guide future research efforts (Zhai et al., 2023).

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7.2. Personalized Medicine and Pharmacogenomics

Recent advances in pharmacogenomics research have identified polymorphic genes crucial for drug absorption, distribution, metabolism, excretion, and target action. Several pharmacogenomic tests are clinically used in various therapeutic areas, particularly oncology. Since the initial report on germline cytochrome P450 2D6-gene variants and tamoxifen response, the US Food and Drug Administration incorporated recommendations into drug labeling for multiple drugs targeting 2D6, 2C19, and thiopurine methyltransferase genes. Technological advances in pharmacogenomic testing are expected to improve drug efficacy and safety and reduce costs. Still, many challenges remain before translating pharmacogenomics into routine clinical practice (W. Francis Lam, 2013).

Pharmacogenomic-guided drug therapy is based on the premise that a large portion of interindividual variability in drug response is genetically determined. While many clinicians and researchers agree that a personalized therapy tailored to an individual's genetic profile is feasible and desirable, it remains some years away (de Leon, 2009). Similarly, the Wide-Screen Pharmacogenomic Assay strategy is unlikely to result in commercially available tests in the near future. Any group considering pharmacogenomic testing should first ensure that a thorough plan addresses the issues discussed.

8. Ethical Considerations in Pharmacy Practice

Pharmacists, as the most accessible healthcare providers, bear the ethical responsibility of upholding professionalism and protecting the rights of patients. Unfortunately, several barriers have been reported in the practice of professionalism in pharmacies. Many patients needing pharmaceutical care services have been left unattended, highlighting the gradual erosion of professionalism within the pharmacy profession. To tackle these challenges, a multidisciplinary outlook involving pharmacists, authorities, and society is imperative to resurrect the profession's commitment toward better health for humanity. Many pharmacists expressed belief in the necessity of patient-centered pharmaceutical care, although the prevailing business models impose obstacles to its implementation. As such, a professional need must be addressed here to stimulate patient-centered practices and gather perspectives on how to overcome barriers impeded by standard business models (Javadi et al., 2018).

The typical day in a high-volume community pharmacy often reflects a disconnect between the ideal of patient-centered pharmaceutical care and the reality. Pharmacists find themselves in an ethically challenging position where the clear conflict between one's professional obligations and the ability to fulfill them is frustrating and disappointing (T. Owens & Baergen, 2021). Employment conditions sometimes change priorities to accommodate corporate focus, resulting in a situation that is unethical and needs to be changed. The endangerment of patient safety and wellbeing due to the inherent design flaws in the business

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model of community pharmacies begs the question: how could community pharmacies be restructured so that patient safety is not compromised? A good first step is to illuminate the conflicts that arise when standard business models are applied in healthcare settings.

8.1. Patient Confidentiality and Data Protection

The community pharmacy is a widely used health care service and an important point of access for consumers to members of the pharmacy profession offering professional services. A feature of these services is the need for pharmacists to ask consumers for medical and personal information to meet their health care needs. While all health professionals need to obtain private personal details, community pharmacy's consumer perception of privacy is complicated. Traditionally, pharmacies resembled retail spaces and community pharmacies still compete with retailers selling non-prescription products. Different consumer expectations of privacy may present a challenge for the delivery of professional services in community pharmacies.

Pharmacy consumers are generally accepting of pharmacists' roles requiring the gathering of personal health information, and the need for this information is understood. Some consumers think that without privacy, pharmacists cannot provide the service adequately. However, there are differences between these consumers in their expectations of privacy. Factors influencing privacy expectations include consumer trust in the pharmacist, an increased comfort level in longer established professional relationships, and a desire for unobtrusive but effective privacy. Sensitivity of the medical and personal information being disclosed impacts on consumers' expectations of privacy. Reluctance to disclose medical and personal information impacts on pharmacists' ability to provide medication management services. Community pharmacists' professional judgement is important in achieving privacy (Laetitia Hattingh et al., 2015).

8.2. Conflict of Interest and Industry Influence

The increasing conflict of interest issues in academia are viewed in the context of the pharmaceutical industry's influence on education, research, and healthcare. The emergence of ethical codes in response to conflicts of interest in the drug culture is explored, including measures that have been taken in medicinal chemistry. The pharmaceutical industry's influence over education, research, and the healthcare of the public due to conflicts of interest is highlighted. Since the 1990s, the industry's marketing has expanded dramatically, especially its promotion of drug treatments. The share of promotional spending directed towards non-physicians has tripled, and this is now dominated by expenditure on patient marketing. Considering the public's expectations, most marketing can only be construed as propaganda (Wolpe et al., 2007).

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Countering this simply with education about marketing's tactics ignores the systemic corruption that persists despite good intentions. The credibility of educated professionals is used to back the industry's marketing and education. The discipline of pharmacy has deep, multifaceted connections with the industry, invasively involving both education and research but potentially obscuring with good intentions systemic problems that can't simply be resolved by good conduct and good character. The ethical codes that have developed in response to conflicts of interest involving the pharmaceutical industry are considered. The implementation, compliance, enforcement, and limits of self-regulation in both academic and professional pharmacy are focused on, as well as the inadequacy of such self-regulation without accountability that comes from outside the discipline. Most attention is directed toward the professional side of pharmacy, seeking a balance between the discipline's necessary connections to industry and the need to avoid systemic corruption.

9. Conclusion and Future Directions

The present review provides a historical perspective on the evolution of pharmacy from traditional herbal remedies to modern pharmaceuticals. The dawn of civilization is marked with the discovery of fire and the use of medicinal plants by humankind. The Greek civilization had a significant contribution in bringing herbs and spices from the East. As the Greco-Roman civilization waned, the Byzantine Empire preserved and expanded knowledge of the ancients. The establishment of monasteries was important for the preservation of manuscripts and healing. Islam was crucial in the advancement of science and brought pharmacy at the forefront as al-sina'a al-nabatiyyah. The Renaissance sparked interest in antiquity with the revival of Greek and Roman texts and the establishment of universities. Pharmacy as a distinct profession began in Europe with the emergence of pharmacy guilds. The discovery of the New World opened new frontiers for exploration and trade. The profession again fell in the hands of quacks and charlatans. The establishment of the United States of America heralded numerous experiments in democracy including that of pharmacy. The 19th century witnessed transformation of pharmacy from an art to a science and the subsequent establishment of regulatory bodies. The advent of modern technology and research chemists freed medicine making from the apothecaries (Tripathi et al., 2018). The present-day pharmaceutical industry evolved during the 20th century from crude extract natural products to modern designer drugs and is still undergoing rapid changes. The pharmaceutical industry is at a crossroad as it moves from the blockbuster drug discovery model to that of drug repositioning, polypharmacology, and personalized medicine. The future of pharmacy as a profession and industry would depend on the new paradigms followed in drug discovery and development.

Epidemiological studies have shown that with advancements in the healthcare systems, the focus of pharmacy is shifting from infectious diseases to lifestyle or chronic diseases. This is

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even more alarming in developing nations where despite great progress in GDP and healthcare spending, the quality of healthcare remains poor and the focus is mainly on the contagious diseases (Azadi et al., 2015). Underdeveloped nations are plagued with a myriad of problems like poverty, illiteracy, corruption, and social inequality. Rapid population growth and urbanization have further strained healthcare systems. Emerging economies like BRICS which are expected to be the economic powerhouse of the world in the 21st century currently face similar challenges with respect to pharmacy. The present mathematical modeling and trend analysis across nations strive to outline the past, present, and future global scenario of pharmacy in general and pharmaceutical industries in particular with respect to population, economy, epidemiology, and drug consumption. The projections would help policy makers to devise short-term strategies at national levels to tackle the emerging pharmaceutical problems.

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