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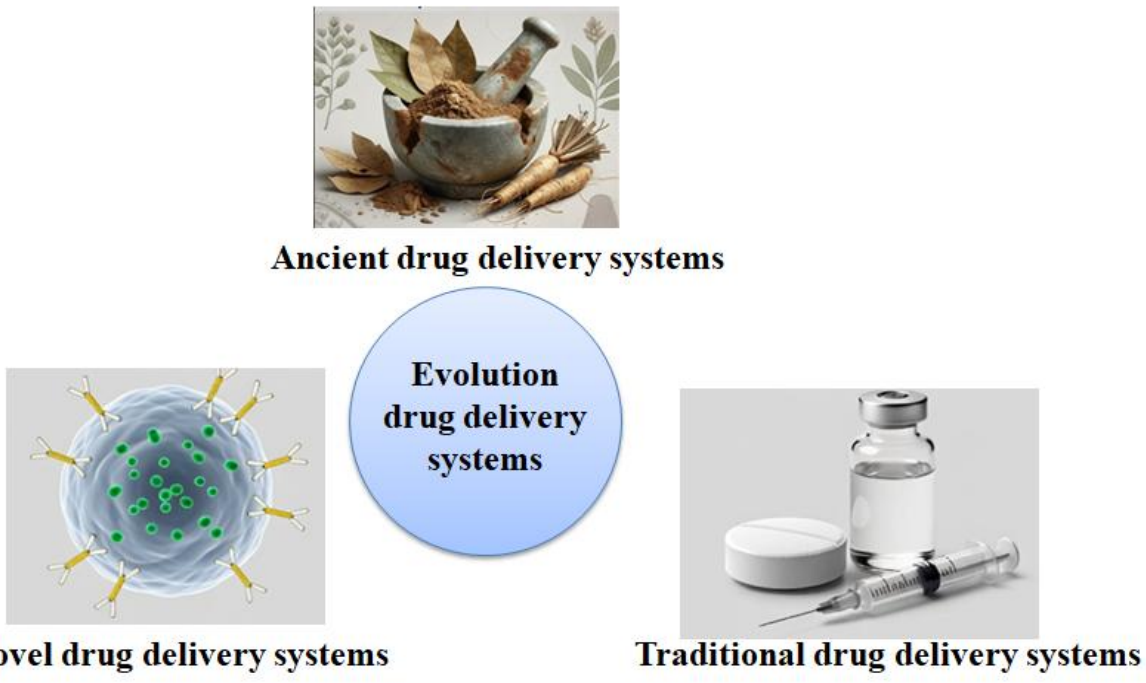
Comparative Analysis of Ancient, Traditional, and Novel Drug Delivery Systems a Theoretical Study

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Abstract*—Drug delivery systems (DDS) have evolved significantly from ancient medicinal practices to sophisticated modern technologies, reflecting continuous efforts to improve therapeutic efficacy, patient compliance, and treatment safety. Ancient drug delivery systems relied primarily on natural substances and simple administration methods, including oral decoctions, herbal powders, medicated oils, poultices, and inhalation therapies, as practiced in civilizations such as Ayurveda (3000BCE), Traditional Chinese Medicine(2000BCE), Egyptian(2500BCE), Greek(500BCE), Roman(100BCE), Persian(500BCE) and native American(1000BCE) medicine. These approaches emphasized holistic healing but lacked precise dosage control and standardized formulations. Traditional DDS introduced scientifically formulated dosage forms such as tablets, capsules, syrups, injections, ointments, and topical preparations. However, traditional DDS often exhibit limitations including poor bioavailability, rapid drug degradation, frequent dosing, and systemic side effects. Novel drug delivery systems (NDDS) address these challenges through advanced nanocarriers viz. nanoparticles, nanotubes, liposomes, nanogels, nanospheres carriers. These innovative platforms enable controlled, sustained, and targeted drug delivery, thereby enhancing therapeutic outcomes while minimizing adverse effects. This theoretical study represents a comparative analysis of ancient, traditional, and modern novel drug delivery systems by examining their historical development, mechanisms of administration, advantages, limitations, and clinical relevance. The study highlights the progressive transformation of drug delivery strategies from empirical herbal preparations to precision nanomedicine and emphasizes the integration of traditional knowledge with advanced pharmaceutical technologies. Such a comparative perspective provides valuable insights for future research aimed at developing safer, more effective, and patient-centered drug delivery systems.

***Index Terms*—Ancient drug delivery, Traditional drug delivery, Novel drug delivery, Nanocarriers, Nanotubes, Nanomedicine.**

GRAPHICAL ABSTRACT



I. INTRODUCTION

The development of efficient drug delivery systems remains a major challenge in modern pharmaceutical sciences. Ancient drug delivery systems were developed independently across different civilizations, reflecting their knowledge of medicine, natural resources, and cultural practices. Although simple compared to modern pharmaceutical technologies, these methods formed the foundation of contemporary drug delivery science. In Ancient India (Ayurveda), medicinal plants such as turmeric, neem, and ashwagandha were administered as powders (churna), decoctions (kwath), medicated oils (taila), and herbal pastes (lepa)[1]. Oral administration with milk, honey, or ghee enhanced absorption and therapeutic efficacy.In Ancient Egypt, natural substances like honey, garlic, and aloe vera were applied directly to wounds and burns[2]. Ointments prepared with animal fats and plant extracts served as topical drug delivery systems, while herbal infusions were commonly used for oral treatment. Traditional Chinese Medicine (China) relied on herbal decoctions, powders, pills, and medicinal teas. Herbs such as ginseng, licorice, and ginger were carefully combined to optimize therapeutic effects[3]. Acupuncture also acted as a unique method of stimulating physiological responses alongside herbal therapy. In Ancient Greece, physicians such as Hippocrates prescribed herbal extracts, wines, syrups, and poultices. Medicinal plants including willow bark and opium poppy were administered orally or applied externally for pain relief and wound healing[4]. The Roman

Empire further advanced drug formulation by preparing medicinal wines, ointments, plasters, and inhaled herbal vapors. Public baths and mineral waters were also integrated into therapeutic practices[5]. In Ancient Persia, physicians utilized herbal syrups, aromatic oils, and distillates prepared from rose, saffron, and other medicinal plants. These formulations improved palatability and preserved the active ingredients[6]. Native American communities delivered medicines through herbal teas, smoke inhalation, poultices, and topical applications using locally available medicinal plants such as echinacea and willow bark[7]. Despite their effectiveness, ancient drug delivery systems often lacked precise dosage control, targeted delivery, and standardized formulations[8]. These limitations ultimately led to the development of conventional pharmaceutical dosage forms and, more recently, advanced drug delivery systems such as nanoparticles, liposomes, hydrogels, and controlled-release formulations.

Conventional/traditional drug delivery systems (CDDS) are the traditional methods of administering therapeutic agents to achieve systemic or localized effects. These systems include oral tablets, capsules, syrups, injections, topical creams, ointments, eye and ear drops, suppositories, and inhalation therapies[9]. They are designed to release the active pharmaceutical ingredient either immediately or over a short period after administration. Oral administration remains the most widely used route due to its convenience, ease of manufacturing, patient compliance, and cost-effectiveness[10]. Injectable formulations provide rapid therapeutic action and are commonly employed in emergency situations or when oral administration is unsuitable[11].Despite their widespread use, conventional drug delivery systems possess several limitations. Many drugs exhibit poor aqueous solubility, limited bioavailability, rapid metabolism, and non-specific distribution, which reduce therapeutic efficacy[12]. Frequent dosing is often required because of short drug half-lives, leading to poor patient adherence. Furthermore, non-targeted drug distribution can expose healthy tissues to the drug, increasing the risk of adverse effects and systemic toxicity. Conventional formulations also offer limited control over the rate and site of drug release, making them less suitable for chronic diseases requiring sustained or targeted therapy[13]. These shortcomings have driven the development of advanced drug delivery systems, including controlled-release formulations and nanotechnology-based carriers, which aim to enhance drug stability, improve therapeutic outcomes, minimize side effects, and provide precise site-specific drug delivery. Nanotechnology offers innovative solutions by designing nanocarriers that can transport therapeutic molecules directly to diseased tissues while minimizing off-target toxicity[14]. Nanovesicles typically range from 1–1000 nm and can encapsulate, adsorb, or conjugate drugs through physical or chemical interactions. Their high surface-to-volume ratio, tunable physicochemical properties, and ability to cross biological barriers have made them attractive candidates for cancer therapy, gene delivery, antimicrobial treatment, and diagnostic applications[15].Among the diverse nanovesicles developed, liposomes, polymeric nanoparticles, dendrimers, micelles, carbon nanotubes (CNTs), graphene derivatives, metallic nanoparticles, and inorganic nanotubes have received considerable attention[16]. Understanding their comparative advantages and limitations is essential for selecting an appropriate carrier for specific biomedical applications. Despite remarkable

advancements in modern drug delivery technologies, a comprehensive scientific comparison of ancient, traditional, and modern drug delivery systems remains limited. Existing literature largely investigates these systems independently, with insufficient emphasis on comparative evaluation of therapeutic efficacy, safety, pharmacokinetics, standardization, sustainability, and clinical applicability. Furthermore, the integration of traditional drug delivery knowledge with emerging technologies such as nanomedicine, artificial intelligence, and precision medicine is still in its infancy. Addressing these gaps could facilitate the development of innovative, evidence-based, cost-effective, and culturally informed drug delivery strategies for future healthcare.

The aim of the present study is to comparatively analyze the evolution of drug delivery systems from ancient and traditional practices to modern pharmaceutical technologies. The study seeks to evaluate their principles, routes of administration, bioavailability, safety, patient compliance, therapeutic efficacy, and limitations. It also aims to identify the scientific basis of traditional drug delivery methods, explore their relevance in contemporary medicine, and highlight existing research gaps. Furthermore, the study intends to examine opportunities for integrating traditional knowledge with advanced drug delivery technologies, such as nanotechnology and targeted delivery systems, to support the development of safer, more effective, and patient-centered therapeutic approaches

II. DRUG DELIVERY SYSTEMS

2.1.ANCIENT DRUGS AND THEIR DELIVERY:

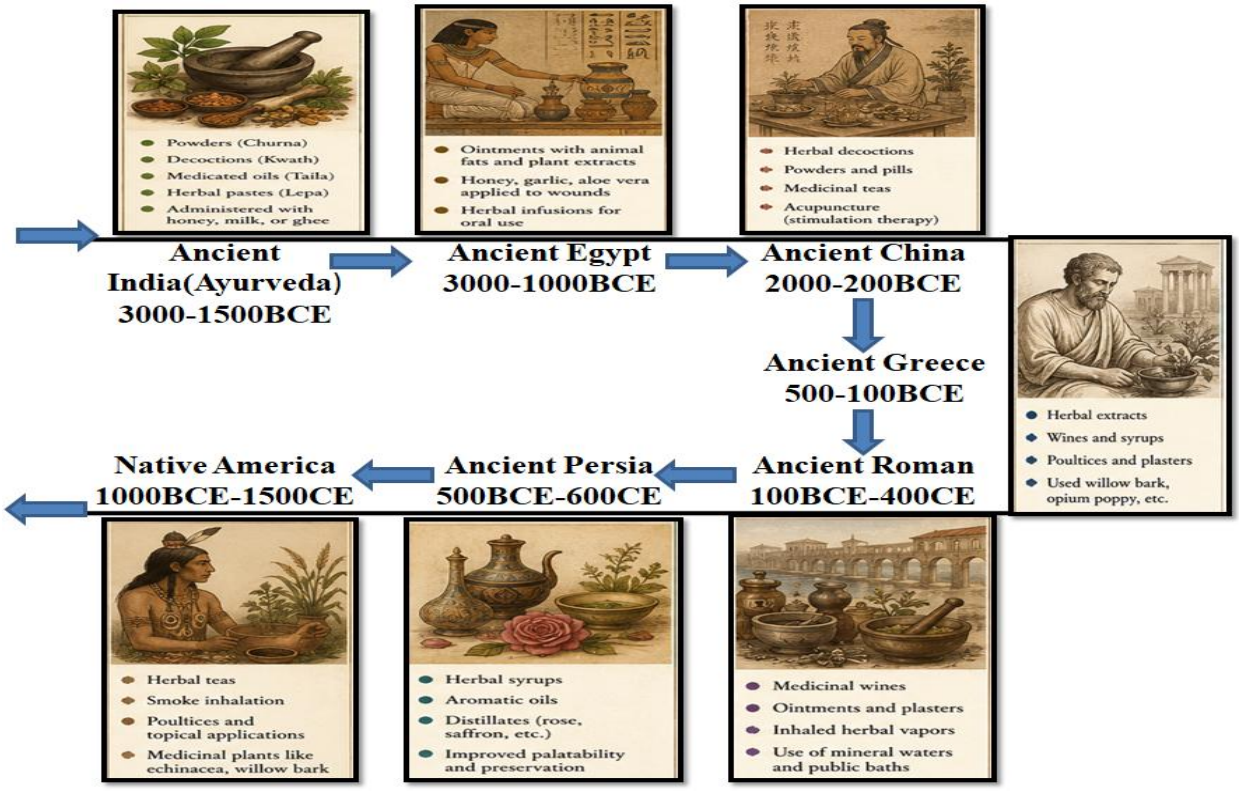


Figure 1: Historical timeline of ancient drug delivery systems.

Ancient drug delivery refers to the methods used by early civilizations to administer natural medicines derived from plants, animals, and minerals. These systems were based on traditional knowledge and empirical observations rather than scientific understanding. In Ancient Indian (Ayurveda-3,000 years ago)drug like Turmeric (Curcuma longa) was delivered through Oral powder with milk, topical paste on wounds against Anti-inflammatory, wound healing, antimicrobial[17]. In addition Ancient Egyptian Medicine (approximately 3000–500 BCE), Honey was used as drug and applied directly to wounds and burns to minimize infection and promoted healing. Moreover, in Traditional Chinese Medicine (TCM) drug like Ginseng (Panax ginseng) was delivered by using Herbal tea (decoction), powder, or pills to improved energy, immunity, and vitality[18]. Interestingly, Ancient Greek Medicine Willow bark was used as drug and delivery was carried out by Chewed or prepared as a decoction for pain relief and fever reduction (contains salicin, the precursor of aspirin)[19] as shown in Figure 1.

Table 1: Different ancient drug and their delivery systems.

Drug delivery Methods	Description	Drugs	Drug delivery systems	Delivery Route	DOI
Oral Administration	Herbs, powders, decoctions, and pills taken by mouth.	Turmeric, Ginger, Garlic, Neem, Liquorice	Powders (churna), decoctions (kwath), medicated oils (taila), and herbal pastes (lepa)	Oral	[20]
Topical Administration	Herbal pastes, oils, ointments, and poultices applied to the skin.	Aloe vera gel, Honey, Sesame oil, Turmeric paste	Direct application or animal fats and plant extracts	Skin	[21]
Inhalation/Fumigation	Medicinal herbs burned or inhaled as smoke or vapour.	Frankincense, Myrrh, Eucalyptus, Camphor	Herbal tea (decoction), powder, or pills	Nasal/Respiratory	[22]
Nasal Delivery	Herbal oils or powders	Anu Taila, herbal nasal	Direct application	Intranasal	[23]

	administered through the nose.	drops			
Rectal Administration	Herbal enemas used for cleansing and treatment.	Herbal decoctions, medicated oils	Direct application	Rectum	[24]
Eye and ear Preparation	Herbal extracts or oils instilled into the eyes or ears.	Rose water, Castor oil, Triphala extract	Direct application	Ocular/Aural	[25]
Wound dressing	Natural substances applied directly to wounds.	Honey, Aloe vera, Ghee, Neem paste	Direct application	Topical	[26]

Table 2: Advantages and disadvantages of ancient drug delivery systems.

Sl.No.	Advantages	Disadvantages
1	Utilized natural and locally available materials.	No controlled or targeted drug delivery.
2	Simple and inexpensive preparation.	Variable drug dosage and potency.
3	Minimal equipment required.	Poor bioavailability for many herbal compounds.
4	Holistic approach to health and wellness.	Short shelf life and stability.
5	Many remedies showed therapeutic effectiveness	Lack of standardization and scientific validation.
6		Frequent administration often required.
7		No controlled or targeted drug delivery.

Ancient drug delivery systems relied on natural substances administered through oral, topical, nasal, inhalation, rectal, and ocular routes. Although these methods lacked precision and standardization, they formed the foundation of modern pharmaceutics and inspired the development of advanced drug delivery systems such as sustained-release formulations, liposomes, nanoparticles, and targeted drug delivery.

2.2 TRADITIONAL DRUGS AND THEIR DELIVERY: Traditional drug delivery (also called conventional drug delivery) refers to standard, immediate-release methods of administering pharmaceutical compounds viz. pills, syrups, and basic injections[27]. These methods are cost-effective, easily accessible, and designed for immediate systemic or local effect, though they often require frequent dosing. Traditional drug administration methods, including oral tablets, capsules, injections, topical formulations, and inhalation therapies, have been the cornerstone of disease treatment for decades. These conventional drug delivery systems are generally simple, cost-effective, and convenient for manufacturing and administration. However, despite their widespread use, they often suffer from significant limitations that reduce therapeutic efficacy and increase the risk of adverse effects[28]. In conventional drug delivery, drugs are distributed throughout the body after administration rather than being selectively delivered to the diseased tissue. As a result, only a small fraction of the administered dose reaches the target site, while the remainder affects healthy tissues, leading to undesirable side effects[29]. Moreover, many drugs exhibit poor aqueous solubility, low bioavailability, rapid metabolism, short circulation half-life, and instability under physiological conditions. These factors often necessitate frequent dosing, resulting in poor patient compliance and fluctuating drug concentrations that may fall outside the therapeutic window[30]. The limitations of traditional drug delivery are particularly evident in cancer chemotherapy. Most anticancer drugs lack specificity and attack both cancerous and healthy rapidly dividing cells, causing severe side effects such as bone marrow suppression, gastrointestinal toxicity, hair loss, and immunosuppression. Additionally, physiological barriers such as the blood-brain barrier, tumor microenvironment, and multidrug resistance mechanisms further reduce drug accumulation at the target site, limiting therapeutic success[31].To overcome these challenges, modern drug delivery systems (MDDS) have emerged as a promising alternative. These systems employ advanced carriers such as nanoparticles, liposomes, dendrimers, polymeric micelles, carbon nanotubes, graphene derivatives, mesoporous silica nanoparticles, and other nanomaterials to improve drug transport and therapeutic performance. Modern drug delivery systems are designed to enhance drug solubility, protect drugs from premature degradation, prolong circulation time, improve bioavailability, enable controlled and sustained release, and facilitate targeted delivery to diseased tissues while minimizing exposure to healthy organs. Targeted and stimuli-responsive drug delivery strategies have further revolutionized modern therapeutics by enabling drug release in response to specific physiological conditions such as pH, temperature, enzymes, redox potential, or external stimuli including light, magnetic fields, and ultrasound[32]. These approaches maximize therapeutic efficacy while significantly reducing systemic toxicity. Consequently, modern drug delivery systems have become an important focus of pharmaceutical and biomedical research. Their ability to improve pharmacokinetic profiles, enhance therapeutic outcomes, reduce adverse effects, and increase patient compliance makes them highly promising for the treatment of complex diseases, particularly cancer, infectious diseases, and neurological disorders[33].

This overview provides a strong rationale for the development of modern nanotechnology-based drug delivery systems that can overcome the limitations of conventional therapies and significantly improve clinical outcomes.



Figure 2: Different types of Traditional drug delivery systems.

2.2.1Core Routes of Traditional Delivery

a)Oral Administration: The most common method, utilizing tablets, capsules, or syrups. It is convenient and cost-effective but often results in poor bioavailability due to stomach acids and "first-pass" metabolism in the liver[34].

b)Parenteral Administration: Injections or infusions directly into the body (intravenous, intramuscular, or subcutaneous). They bypass the digestive tract for rapid absorption, but they are invasive and often require administration by a healthcare professional[35].

c)Topical Application: Creams, ointments, or lotions applied directly to the skin or mucous membranes to treat localized conditions (e.g., skin infections, rashes)[36].

d)Transmucosal Administration: Medications absorbed through mucous membranes, including sublingual (under the tongue), rectal, and vaginal routes. These avoid liver metabolism and offer faster absorption than oral pills[37].

2.2.2 Major Drawbacks of Traditional Drug Delivery

a) Non-specific distribution throughout the body.
b) Low bioavailability due to poor solubility and first-pass metabolism.
c) Rapid drug degradation and short half-life.
d) Frequent dosing requirements.
e) High systemic toxicity and adverse side effects.
f) Poor penetration across biological barriers.
g) Inability to achieve controlled or sustained drug release.
H) Limited drug accumulation at the target site.

I) Reduced patient compliance.
J) Development of drug resistance in chronic diseases such as cancer.

2.3 MODERN DRUGS AND NOVEL DRUG DELIVERY SYSTEMS

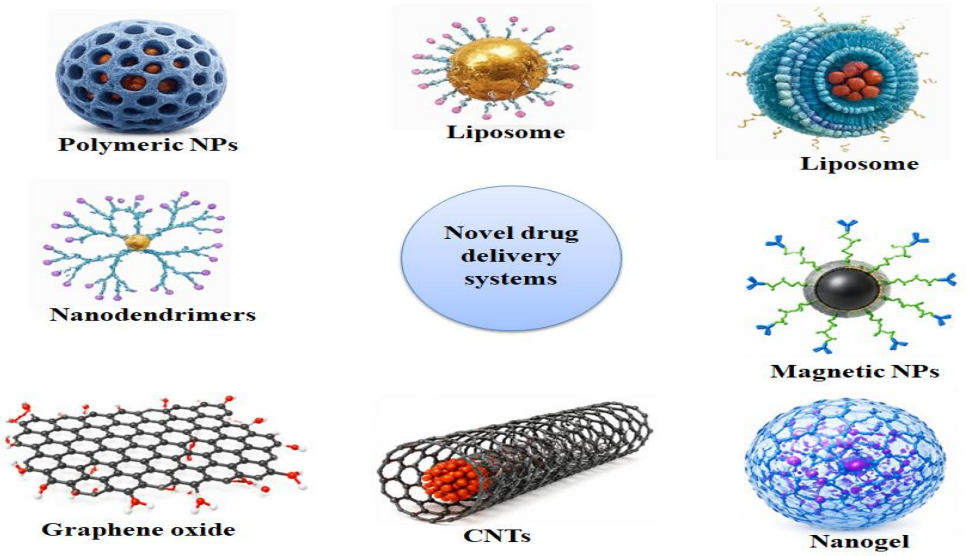


Figure 3: Novel drug delivery systems for sustainable drug release.

2.3.1 Nanoparticle:

Organic polymers composed of phospholipid and cholesterol. Bilayered lipids containing neutral aqueous portion. The lipids are cationic and neutral of phosphatidylcholine class and sterols biodegradable, biocompatible, amphiphilic, alternating lipid modification and drug delivery capacity, liposome, niosomes formed by self-association of nonionic surfactants and cholesterol in an aqueous phase[38]. Biodegradable, biocompatible, have nonimmunogenic skeleton, and therefore serve as promising drug carriers. Inorganic metallic nanoparticles such as gold nanoparticles (AuNPs), silver nanoparticles show better advantages like excellent biocompatibility,easy surface modification and strong optical properties[39]. Few disadvantages are high cost. And limited drug loading compared to porous carriers. Silver nanoparticles (AgNPs) show Strong antimicrobial activity and easy synthesis[40].

2.3.2 Liposomes

Liposomes are phospholipid vesicles composed of one or more lipid bilayers surrounding an aqueous core. They are among the earliest FDA-approved nanocarriers. There are several advantages like excellent biocompatibility and biodegradability, capable of loading both hydrophilic and hydrophobic drugs, reduced systemic toxicity and clinically established technology[41]. They show limited disadvantages limited physical stability and drug leakage during storage .Anticancer drug like doxorubicin has delivered through it. They also helps in gene therapy and vaccine delivery[42].

2.3.3 Polymeric Nanoparticles

Polymeric nanoparticles are prepared from biodegradable polymers such as PLGA, PEG, chitosan, and alginate. Polymers with suspended nanosized substances/drugs, synthetic and natural origin biodegradable and biocompatible polymers are used[43]. Their advantages are controlled and sustained drug release, high drug encapsulation efficiency, tunable particle size and surface chemistry with improved circulation time. Limited disadvantages are Complex synthesis procedures, potential polymer toxicity. and batch-to-batch variability.Polymeric NPs has several applications viz. anticancer therapy, protein delivery, and vaccine formulations[44].

2.3.4 Polymeric Micelles

Micelles are self-assembled nanostructures formed from amphiphilic block copolymers. Their advantages are excellent solubilization of hydrophobic drugs, small particle size enhances tumor penetration. and Prolonged blood circulation[45]. Disadvantages are limited loading of hydrophilic drugs. ,possible premature disassembly and stability issues in physiological conditions. Applications of polymeric micelles are paclitaxel delivery and tumor-targeted chemotherapy[46].

2.3.5 Nanodendrimers

Dendrimers are highly branched, monodispherse macromolecules with numerous surface functional groups. Several advantages of dendrimers are precise molecular architecture, high drug loading capacity, easy surface functionalization , and efficient gene delivery[47].Disadvantages are Expensive synthesis, cytotoxicity of cationic dendrimers, complex purification processes. Dendrimers are applied in gene delivery, anticancer drug delivery and diagnostic imaging[48].

2.3.6 Carbon Nanotubes (CNTs)

CNTs are cylindrical carbon nanostructures possessing extraordinary mechanical, thermal, and electronic properties. In modern science nanotube mediated drug delivery has catched the stage and immensely studied area[49] .Their advantages are extremely high surface area, exceptional drug adsorption capability, easy chemical functionalization, efficient cellular uptake, strong π–π interactions with aromatic drugs[50]. Potential cytotoxicity is main concerning issue of it. Various Applications of CNTs are anticancer drug delivery, gene delivery, photothermal therapy, biosensing. Recent computational studies demonstrate that capped CNTs exhibit stronger adsorption and enhanced stability with several anticancer drugs, making them promising nanocarriers for controlled drug release[51].

2.3.7 Inorganic Nanotubes (ZnONTs, BNNTs, GaPNTs)

Emerging inorganic nanotubes have attracted attention due to their tunable electronic properties and enhanced drug adsorption behavior. Their advantages are High structural stability.Strong adsorption energies, tunable electronic characteristics, and enhanced selectivity toward specific

drugs[52]. Limitations are limited biological studies, uncertain long-term toxicity and difficult large-scale synthesis. Several applications of inorganic nanotubes are targeted drug delivery, biosensing and nanoelectronics-assisted therapeutics. Recent theoretical investigations suggest that GaPNTs and ZnONTs may exhibit stronger drug-carrier interactions than pristine CNTs, enabling improved loading efficiency and controlled release performance[53].

2.3.8 Graphene Oxide Nanocarriers

Graphene oxide possesses a two-dimensional sheet-like structure enriched with oxygen-containing functional groups. Due to its large surface area, it has high drug loading efficiency with excellent functionalization capability and photothermal properties[54]. Disadvantages are aggregation tendency. And biocompatibility concerns. Applications of grapheme oxide are chemotherapy, photothermal therapy, and theragnostic platforms[55].

2.3.9 Mesoporous Silica Nanoparticles (MSNs)

MSNs contain highly ordered porous structures capable of storing large amounts of therapeutic molecules. Advantages of MSNs are high surface area and large pore volume, for this Controlled drug release is occurred. Slow biodegradation is major disadvantage. Various applications like controlled release formulations, cancer therapy, protein delivery are observed[56].

2.3.10 Nanogel

Nanogels are three-dimensional, nanosized cross-linked polymer networks that can absorb and retain large amounts of water or biological fluids. They typically range in size from 20 to 200 nm, making them suitable for drug delivery applications[57]. Nanogels can encapsulate both hydrophilic and hydrophobic drugs, improving their stability and bioavailability. They exhibit excellent biocompatibility and biodegradability, reducing the risk of toxicity in the body. Their high drug-loading capacity enables efficient transport of therapeutic agents[58]. Nanogels provide controlled and sustained drug release, minimizing frequent dosing and improving patient compliance. They can be surface-functionalized with ligands, antibodies, or peptides for targeted drug delivery to specific tissues or cancer cells. They have applications in cancer therapy, gene delivery, vaccine delivery, wound healing, antimicrobial therapy, and tissue engineering[59].

Table 3: Different types of novel drug delivery systems and their delivered drugs.

Novel drug delivery	Advantages	Delivery mode	Delivered drugs	Particle size (Diameter)nm	DOI number

CNTs	Less toxic, Non immunogenic, Target delivery, Sustainable drug release.	Intravenous inject	Doxorubicin, Paclitaxel, Methotrexate, Gemcitabine, Docetaxel, 5-Fluorouracil, Camptothecin, Carboplatin.	0.5 – 100 nm	[53]
Nanoliposome	Superior bioavailability, targeted precision, and biocompatibility.	Oral delivery, Transdermal delivery, Pulmonary delivery.	Doxorubicin, Irinotecan, Daunorubicin, Cytarabine, Vincristine.	10 to 100 nm	[60]
Nanosphere	Increasing bioavailability, protecting sensitive drugs from degradation.	Intranasal delivery, Transdermal delivery	Paclitaxel, Doxorubicin, Irinotecan, Cytarabine, Amphotericin B, Curcumin.	10 - 200 nm	[61]

Polymeric NPs	Protecting sensitive therapeutics from degradation, improving the solubility of hydrophobic drugs, and prolonging systemic circulation.	Ocular delivery, Systematic routes, Ocular delivery.	Paclitaxel, Dexamethasone, Methotrexate	10 - 200 nm	[62]
Nanodendrimers	High drug encapsulation, site-specific targeting, and prolonged circulation times	Intravenous, intranasal, topical.	Docetaxel , Cabazitaxel	1-15nm	[63]
Quantum dots	Highly targeted, site-specific delivery, Enhanced drug loading capacity, and real-time tracking.	Intravenous, topical.	Doxorubicin, Adriamycin, Cisplatin, Busulfan	2-10nm	[64]
Mesoporous silica NPs	Massive surface area, tunable pore sizes (2 nm to 50 nm), and exceptional biocompatibility.	Oral,intravenous.	Doxorubicin, Paclitaxe,l Camptothecin, Vancomycin	2-50nm	[65]
Solid lipid NPs	Biocompatibility , Ability to encapsulate both hydrophilic and lipophilic compounds, and prolonged drug release	Parenteral, oral, topical/transdermal, ocular, pulmonary, and intranasal.	Paclitaxel, Doxorubicin, Doxycycline, Risperidone, Alendronate sodiu	50-200nm	[66]

			m		
Magnetic NPs	Highly targeted drug delivery.	Intravenous	Doxorubicin, Paclitaxel, Methotrexate,	20nm	[67]
Nanogel	Massive drug-loading capacity for both hydrophobic and hydrophilic molecules, superior stability.	Oral, parenteral (intravenous), pulmonary, nasal, intraocular, and topical	Doxorubicin, Levofloxacin, Paclitaxel.	10-200nm	[68]
Nanocystal	Enhanced Bioavailability, high drug loading, deep tissue penetration.	Oral, intravenous, pulmonary, and ocular systems.	Doxorubicin.	1-100nm	[69]

2.4. Comparative Summary of Nanovehicles.

Table 4: Comparative analysis of different nanocarriers.

Nanovehicle	Drug Loading	Biocompatibility	Targeting Ability	Stability	Toxicity Risk
Liposomes	Moderate	Excellent	High	Moderate	Low
Polymeric NPs	High	Good	High	High	Low-Moderate
Micelles	Moderate	Good	Moderate	Moderate	Low
Dendrimers	High	Moderate	High	High	Moderate
CNTs	Very High	Moderate	High	Excellent	Moderate-High
Graphene Oxide	Very High	Moderate	High	Good	Moderate
Gold NPs	Moderate	Excellent	High	Excellent	Low

Silver NPs	Moderate	Moderate	Moderate	Excellent	High
MSNs	Very High	Good	High	Excellent	Moderate
Inorganic NTs	Very High	Under Investigation	High	Excellent	Under Investigation

III. COMPARATIVE ANALYSIS OF DIFFERENT DRUG DELIVERY SYSTEMS IN DIFFERENT TIME SCALE.

From ancient to modern time scale drug delivery systems has gradually evolved with their efficacy and effectiveness for achieving controlled and targeted delivery to reduce toxicity, severe side effects, here is the comparison that clearly stated the drug sources, drug accuracy, bioavailability, stability, safety concern.

Table 5: Comparative analysis of Drug delivery.

Parameter	Ancient drug delivery	Traditional drug delivery	Novel drug delivery
Scientific basis	Empirical and cultural knowledge	Established pharmaceutical science	Advanced pharmaceutical, biological, and engineering principles
Drug source	Mainly natural materials	Purified synthetic, semi synthetic, or natural drugs	Conventional drugs, biologics, genes, and complex therapeutic agents
Dose accuracy	Low and variable	Generally high	High, with programmable release capability
Drug release	Uncontrolled	Usually immediate or moderately modified	Controlled, sustained, delayed, pulsatile, or stimuli responsive
Target specificity	Very low	Usually limited	Can be tissue-, cell-, or receptor-specific
Bioavailability	Unpredictable	Variable and route dependent	Designed to improve absorption and exposure
Stability	Often poor	Improved through formulation and packaging	May include advanced protection from degradation
Dosing frequency	Often uncertain	Frequently repeated	Often reduced
Manufacturing	Manual or local	Industrial and standardized	Requires specialized equipment and quality control
Quality control	Limited	Well established	Extensive and technologically demanding
Safety assessment	Incomplete	Regulated and systematic	Requires additional evaluation of carriers, nanomaterials, and long-term effects
Cost	Usually low	Moderate	Often high
Patient compliance	Variable	Moderate to good	Potentially improved

IV. CONCLUSION

Ancient drug delivery systems laid the foundation for medicinal therapy using natural resources but suffered from poor dose control and limited efficacy. Conventional drug delivery systems standardized pharmaceutical treatments and improved therapeutic outcomes; however, they often lack precise targeting and controlled release. Modern novel drug delivery systems overcome these limitations through advanced technologies such as nanotechnology, biodegradable polymers, liposomes, dendrimers, and carbon nanotubes, enabling targeted, controlled, and sustained drug release. These systems enhance therapeutic efficacy, minimize adverse effects, improve patient compliance, and represent the future of precision medicine. Nanovehicle-based drug delivery systems have transformed modern therapeutics by addressing limitations associated with conventional drug administration. Liposomes and polymeric nanoparticles offer excellent biocompatibility and have achieved clinical success, while dendrimers and micelles provide controlled release and targeted delivery capabilities. Carbon nanotubes, graphene derivatives, mesoporous silica nanoparticles, and emerging inorganic nanotubes exhibit exceptionally high drug loading capacities and unique physicochemical characteristics that make them attractive candidates for next-generation nanomedicine. Despite remarkable progress, challenges related to toxicity, biodegradability, large-scale production, and regulatory approval continue to hinder clinical translation. Future advancements in nanocarrier engineering, functionalization strategies, and personalized medicine are expected to facilitate the development of safer, more efficient, and highly selective drug delivery systems for cancer therapy and other biomedical applications.

Declaration of Competing Interest: There are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this review by the authors.

Conflicts of interest: The Authors declare that they have no conflict of interest.
Ethics approval and consent to participate: This Study contains no animal or human studies. Hence, ethical approval is not required.

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