# Nanoparticles drugs delivery and conventional drug delivery and future prospects

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**Abstract: Nanomedicine and nano delivery systems are an exciting and rapidly growing field where tiny materials, at the nanoscale, are used as tools to diagnose diseases or deliver medicines directly to specific parts of the body. This technology offers many advantages, especially for treating chronic illnesses, by ensuring medicines are delivered precisely where they are needed.**

**Recently, nanomedicine has been used successfully for a variety of treatments, including chemotherapy, immunotherapy, and biological therapies. These advancements have improved the effectiveness of both new and traditional medicines, including natural products, and have enhanced the ability to detect diseases using specific markers.**

**This review highlights recent progress in nanomedicine and nano drug delivery systems, focusing on how nanomaterials have improved drug performance and diagnosis. It also explores the opportunities and challenges of using nanomedicines, from their creation (synthetic or natural) to their use in real-life medical treatments. Additionally, the review discusses current trends and future possibilities in the field of nanomedicine, presenting a clear and simple overview of its potential .**

**Keywords: Enhanced permeability and retention (EPR), Polymeric nanoparticles (PLGA, PEG).**

## INTRODUCTION

Drugs are defined by FDA, in part, as “intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease” and “articles (other than food) intended to affect the structure or any function Of the body of man or other animals. It is expected that the drugs are

Capable of targeting the disease-causing cell with an exact therapeutic Concentration in an effective manner. However, in contrast, it is observed that release rate, stability and cell- and tissue-specific targeting ability are uncontrolled and cannot be monitored [1]. To overcome Challenges, drug delivery system is designed. Drug delivery system has the capability to regulate drug release rate and improves the effectiveness of the drug (Fig. 1) [2].

Designing of drug delivery system includes the study of engineeringConcepts, material design, implementation techniques and clinical Application. Engineering concepts focuses on the diffusion, erosion, Degradation, shear, swelling, binding kinetics, passive cell uptake, surface area and active cell uptake. Material design includes two systems-Controlled drug delivery system and self-emulsifying system [2]. Controlled drug release system is classified as matrix, reservoir, degradable material, hydrogel, osmotic pump and erodible material. In Matrix system, drug is released through interconnected pores. In reservoir system, drug permeates through the semipermeable membrane. In Degradable material system, the material degradation causes porous Structure leading to extrusion of drug. Hydrogel system release drug Via constrain mesh. In osmotic pump system, drug is released due to Change in osmotic pressure through hole/ holes in impermeable membrane. In erodible material, drug is released when the material gets Dissolved1. Self-emulsifying drug delivery system are composed of Oil, surfactant, co-surfactant and drug and when diluted with water Result in micro or nano emulsion [3]. Implementation techniques are Medium via which drug can be delivered such as microsphere (spherical particle with diameter in range between 1–1000 μm) [4] and tubular vesicles (persistent length is greater than microsphere) [5]. Clinical Application involves the investigation of drug validity as per the clinical view point [2].

### Nanoparticles and drug delivery

Drug delivery and related pharmaceutical development in the context of nanomedicine should be viewed as science and technology of nanometer scale complex systems (10–1000 nm), consisting of at least two components, one of which is a pharmaceutically active ingredient (CitationDuncan 2003; CitationFerrari 2005), although nanoparticle formulations of the drug itself are also possible (CitationBaran et al 2002; CitationCascone et al 2002; CitationDuncan 2003; CitationKipp 2004). The whole system leads to a special function related

to treating, preventing or diagnosing diseases sometimes called smart-drugs or theragnostics (CitationLaVan et al 2003). The primary goals for research of nano-bio-technologies in drug delivery include: More specific drug targeting and delivery, Reduction in toxicity while maintaining therapeutic effects,Greater safety and biocompatibility, and Faster development of new safe medicines.

The main issues in the search for appropriate carriers as drug delivery systems pertain to the following topics that are basic prerequisites for design of new materials. They comprise knowledge on (i) drug incorporation and release, (ii) formulation stability and shelf life (iii) biocompatibility, (iv) biodistribution and targeting and (v) functionality. In addition, when used solely as carrier the possible adverse effects of residual material after the drug delivery should be considered as well. In this respect biodegradable nanoparticles with a limited life span as long as therapeutically needed would be optimal.

Limitations of conventional drug delivery systems

e.g., poor bioavailability, systemic toxicity).

Emergence of nanotechnology in healthcare.

Conventional Drug Delivery Systems

Common routes (oral, intravenous, topical, etc.).

Mechanisms of drug release and absorption.

Limitations

1) Poor targeting ability leading to off-target effects.
2) Reduced efficacy in chronic and site-specific diseases.
3) Issues with patient compliance due to dosing frequency

Nanoparticle Drug Delivery Systems

Definition and Types of Nanoparticles

Lipid-based nanoparticles (liposomes, solid lipid nanoparticles Polymeric nanoparticles (PLGA, PEG).

Inorganic nanoparticles (gold, silica).

Biological nanoparticles (exosomes). Mechanisms of Action Enhanced permeability and retention (EPR) effect.

Controlled and sustained drug release.

Active targeting using ligands.

Advantages Over Conventional Systems

1) Improved drug solubility and bioavailability.

2) Reduced systemic toxicity.

3) Site-specific targeting and precision therapy.

Current Applications

Cancer therapy (e.g., doxorubicin-loaded liposomes).

Neurodegenerative diseases (e.g., nanoparticle-mediated BBB crossing)

Infectious diseases (e.g., antiviral and antibiotic delivery).

Challenges and Limitation

Nanoparticle-Based Systems

Biocompatibility and toxicity concerns. High production costs.Regulatory hurdles and clinical translation.

Conventional Systems

Challenges in addressing complex diseases.

Limited advancements in personalization.

1. Future Prospects

Advances in Nanotechnology

Development of hybrid nanoparticles.

Integration of AI and machine learning for design.

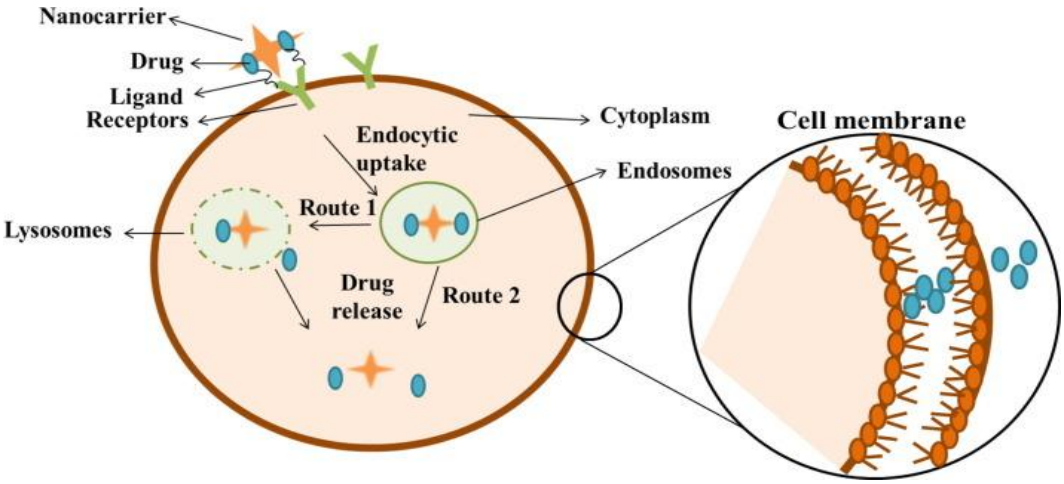
Personalized medicine approaches. Regulatory and Manufacturing Innovations Standardizing nanoparticle production. Accelerated approval pathways for novel systems.

Potential Game-Changers Multifunctional nanoparticles for theranostics. Biodegradable and eco-friendly materials.Combining nanotechnology with gene and cell therapies.

Mechanism of targeted drug release

Targeted drug delivery system is system in which pharmacokinetic drug is transported to the site of action and prevents the unnecessary interaction with other healthy tissue to avoid side effects Non-targeted drug delivery such as chemotherapeutic drug used for cancer treatment leads to undesirable effect on healthy cells. Targeted drug delivery improves the uniformity of the drug effect and reduces the drug

dosage . Targeted drug release is a three-step process: (i) through multivalent receptor–ligand interactions nanocarrier binds with the receptors of the target cell, (ii) through endocytosis drug nanocarrier enters into the cell and (iii) in the last step drug release takes place. Targeted drug delivery can take place in cytosol and cell membrane by interacting with lipid membrane (Fig. 2).




Pharmacokinetics

The essence of pharmacology is the relationship between the dose of a drug given to a patient and the resulting change in physiological state (the response to the drug). The absorption, distribution, metabolism, and excretion of a molecule define its pharmacokinetics, and many of these processes, in turn, are controlled by the physicochemical properties of the molecule. Pharmacokinetic helps in understanding these four important processes

Absorption

Absorption step refers to the movement of drug from the administration site to the body circulation system. Absorption of drug to the systemic circulation can occur via five routes such as transcellular absorption, pinocytosis, transport protein mediated absorption, paracellular, and endocytosis . Low aqueous solubility and poor permeability of drug are the main obstructions in drug absorption . Adsorption of an nanocarrier occurs via internally interacting with organism or permeating through biobarriers (Su et al., 2019). In a study it was reported that permeability of transdermal drug delivery can be improved by using microneedle in the presence of ultrasound . Nanostructures are also one of the ways to overcome these drawbacks. Nanostructures can be fabricated using electrospinning to improve efficacy and avoid loss of effectiveness of active component

Distribution

At distribution stage, drug moves from systemic circulation to the tissue. Nanocarrier helps in prolonging the blood circulation and promote target delivery (Su et al., 2019). One of the major challenges in drug distribution is blood brain barrier, which can be improved by intranasal administration, transcytosis or direct injection of drug to the central nervous system . For instance, in a study, it was recorded that on exposure to ultrasound, permeability improved, releasing the ultrasmall super-paramagnetic iron oxide nanoparticles from the microbubles and opened the blood brain barriers

Metabolism

Metabolism is a process of breaking down drug using enzymes, which can occur in liver, gastrointestinal tract, kidneys, lungs or skin. There are two phases for metabolism of drug, but in some cases both the phase occurs simultaneously for complete metabolism . Nanocarrier are removed from the body via structural degradation (Su et al., 2019). In a study it was reported that immobilization of Cytochrome P450 onto electron can eliminate the need of NADPH. Hence, it can enhance the metabolism process by reducing the complications . Thus, these factors need to be considered while designing of drug .

Elimination

Elimination of drug and metabolites can occur via several routes but the most significant is via kidney. Elimination via kidney involves glomerular filtration, secretion of active tubular and then reabsorbs tubular . Excretion can occur via sweat, bile, urine, breast milk and saliva . Elimination of nanocarriers depends on shape, size and charge of the nanocarriers (Su et al., 2019).

Targeted delivery of nano drug can be obtained via intercellular transport, intracellular transport, controlling particle size, enhanced permeability and retention, coating with hydrophilic component (unhygenic) and conjugating with other materials such as peptide. These methods facilitate the adsorption, metabolism, distribution and excretion of drug. It also helps in reducing the cytotoxicity against normal cells and enhances the efficacy

Pharmacodynamics

Pharmacodynamics is the process to determine the magnitude and type of drug responses when it reaches the site of action using quantitative tools. Drug response can be defined as the chemical interaction between drug and binding site. Binding site (its known as receptors if it consists of functional activity) are the sites at which drugs bind to macromolecule. Drug binding leads to activation of receptors and influences the intracellular messengers or proteins.

## CONCLUSION

Summarize how nanoparticle-based systems offer transformative potential but require overcoming challenges like cost, scalability, and regulatory barriers. Emphasize the role of interdisciplinary collaboration in shaping the future of drug delivery.

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