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INVISIBLE ENGINES OF INNOVATION

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Article Info

Abstract

The term "nanotechnology" describes the atomic, molecular, and macromolecular size exploration and technology development that results in the controlled manipulation and disquisition of structures and devices with length scales ranging from one to one hundred nanometers. At this scale, objects like" nanoparticles" acquire unique characteristics and places that set them different from those observed at the bulk scale. Because of their unique characteristics, nanomaterials can interact in unknown ways with intricate natural processes, indeed at the scale of individual proteins. The significance of nanotechnology has been demonstrated in a number of fields, including medical, by recent developments, it can also be applied in the field of oncology for the diagnosis and therapeutic purpose. The practical operation of nanotechnology to clinical cancer care is still in its infancy, despite its broad interest.

Keywords:

Nanotechnology, Nanostructured, Anthropogenic, Bioinspired, Intriguing.

INTRODUCTION

Nanotechnology is the study and manipulation of matter at sizes ranging from 1 to 100 nm, where special phenomena allow for new uses. The definition of a "nanometer" was initially put forth by chemistry Nobel laureate Richard Zsigmondy in 1925. He used a microscope to quantify the size of particles like gold colloids for the first time and specifically created the term "nanometer" to describe particle size. It was Richard Feynman, the physics Nobel laureate in 1965, who invented modern nanotechnology. He introduced the idea of atomic-level matter manipulation in his lecture "There's Plenty of Room at the Bottom," which was given at the 1959 American Physical Society meeting at Caltech. Feynman's theories have now been shown to be accurate, and this innovative concept revealed fresh ways of thinking. He is regarded as the founder of contemporary nanotechnology because of these factors. Interest in the new disciplines of nanoscience and nanotechnology grew at the start of the twenty-first century. Feynman's reputation and his theory of atomic-level matter manipulation were crucial in determining national science goals in the US[1]. Nanotechnology promises the ability to precisely machine and delineate atomic-sized parts. Therefore, "nanotechnology" refers to the developed ability to create things from the ground up using tools and processes that are being described to create better products. Nanotechnology, according to the National Science Foundation, is the ability to understand, manipulate, and control matter down to the level of individual atoms and iotas[2]. Engineering, chemistry, physics, biology, and medicine are among the various fields that nanotechnology integrates with the ultimate goal of producing "things" at the atomic level. Nanoparticles (NPs), nanomaterials, and nanostructured materials are created through chemical, molecular, and supramolecular manipulation. Studying the unique characteristics seen when the size of the nanoparticles is altered, especially decreased, is another area of interest for nanotechnology. Specifically, when compared to bulk particles, nanoparticles smaller than 10 nm have unique characteristics[3, 4]. Furthermore, the optical, electrical, and magnetic properties of the nanomaterial are significantly changed by size reduction. Numerous classifications have been used to classify nanomaterials because of their differences in dimensions, morphologies, sizes, compositions, porosity, phases, and homogeneity. Many types of nanomaterials have been described and many more will be developed. Nanomaterials can also be classified into naturally occurring, incidental, bioinspired, and engineered nanomaterials in function of their origin. Naturally occurring nanomaterials form during natural physicochemical processes. Incidental nanomaterials, also known as anthropogenic or waste particles, occur because of man-made industrial processes. Engineered nanomaterials are fabricated in the laboratory/industry to obtain materials with specific features. Bioinspired are engineered nanomaterials the properties of which mimic those of natural nanomaterials or living matter. Due to the requirement for large-scale production and risk assessment procedures, only a small number of engineered and bioinspired nanomaterials have been authorized and utilized in the industry despite their unique qualities. Erick Drexler popularized the concept of nanotechnology in 1986 with his book "Engines of Creation: The Coming Era of Nanotechnology." Nanotechnology is portrayed in this work as a cutting-edge field. Numerous nanomaterials have recently been created that significantly improve bulk material properties including strength, conductivity, toughness, and light weight while also adding novel and intriguing properties like self-healing, self-cleaning, anti-freezing, antibacterial, and so on[5]. They are now utilized in safety sensing components, construction material reinforcement, and other biological applications, such as medication delivery systems and biosensors. Nanoparticles are employed extensively due to their size- and shape-specific effects that improve the material's external aspect, even in spite of all these potential benefits. Furthermore, the majority of nanomaterials utilized in industry are embedded in nanocomposite materials, which create matrix or inert materials (such as cement or polymer). The American National Standards-established Nanotechnology Standards Panel announced the following priorities for nanotechnology standardization: (i) establishing terminology to characterize the structure and characteristics of materials resulting from nanoscience and nanotechnology, (ii) creating metrology research and standard test procedures, and (iii) assessing the risk, toxicity, and environmental effects of these novel materials. The study of matter at the nanoscale scale, particularly the size-dependent features of solid-state materials, is referred to as nanoscience as opposed to nanotechnology. Since the earliest investigations into atom sizes, researchers have been interested in this subject. In order to comprehend and work with materials at the atomic and molecular scales, nanoscience integrates several fields, including biology, materials science, and physics. Nanotechnology, on the other hand, refers to the ability to view, quantify, work with, and create nanomaterials[5].

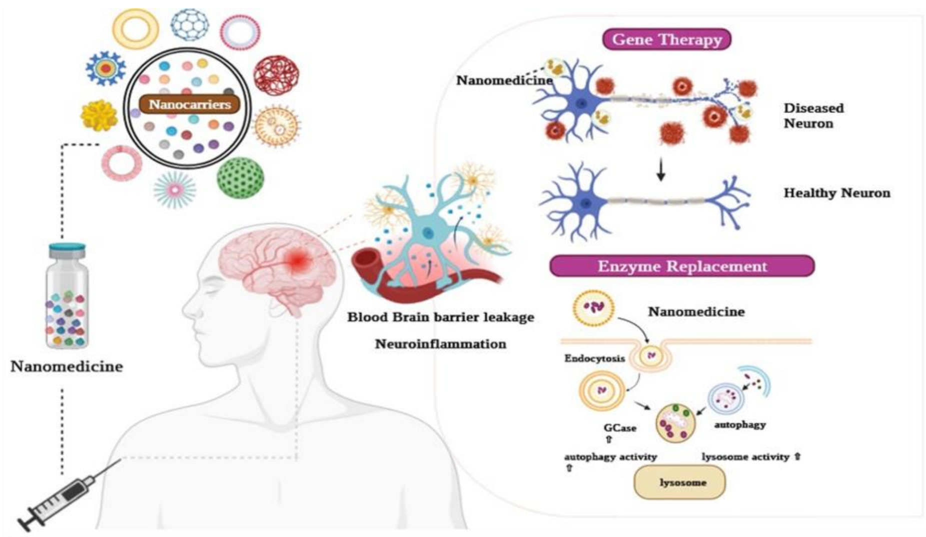

Fig. 1 Advancements in Nanomedicine for Neurological Disorders

Nanomedicine plays a crucial role in treating neurological conditions by enabling targeted drug delivery. The image highlights two key applications: gene therapy, where nanocarriers help repair diseased neurons, and enzyme replacement, which enhances cellular processes like lysosome activity. These advancements improve treatment efficacy by overcoming challenges like blood-brain barrier leakage and neuroinflammation.[6] **Fig. 1**

Nanotechnology has significantly contributed to the treatment of various diseases, leading to enhanced therapeutic outcomes and greater clinical success.[6] **Table 1**

Nanomedicine involves the comprehensive study, regulation, development, repair, and enhancement of human biological systems at the molecular level, utilizing engineered nanodevices and nanostructures. It is recognized as both a science and a technological approach for diagnosing, treating, and preventing diseases and injuries, alleviating pain, and improving overall human health through molecular tools and an in-depth understanding of the body's subatomic mechanisms.[7] **Table 1**

Table 1 NANOTECHNOLOGY IN DRUG DELIVERY SYSTEMS

ARTICLE	AIMS AND OBJECTIVES	CONCLUSION	REFERENCES

Nanotechnology-based drug delivery for the treatment of CNS disorders.	This study develops biodegradable, biocompatible nanoparticles engineered to cross the blood-brain barrier for targeted brain drug delivery. It focuses on enhancing therapeutic efficacy through dual-functional surface modifications, controlled drug release, and testing in in-vitro and in-vivo models.	Nanotechnology offers a promising approach for treating CNS disorders by enabling targeted drug delivery across the blood-brain barrier, enhancing efficacy and reducing side effects. However, further research is needed to ensure safety and understand long-term effects.	**[8]**
Nanotechnology-based ocular drug delivery systems: Recent advances and future prospects.	This research aims to enhance ocular drug delivery using nanocarriers like nanoparticles and micelles to improve permeability, retention, and targeted or sustained release therapies.	Nanocarrier-based systems enhance ocular drug delivery by improving targeting and bioavailability, with ongoing research addressing challenges to unlock their full potential in treating eye diseases.	**[9]**
Nanotechnology-based drug delivery systems for the treatment of anterior segment eye diseases.	This research aims to develop nanocarrier-based ocular drug delivery systems to enhance bioavailability and effectiveness in treating ASED, with efficacy and safety evaluated through in vitro and in vivo studies.	Despite progress, treating ASED remains challenging, requiring stable, long-lasting nanocarriers with improved bioavailability, calling for collaborative research to develop advanced, patient-friendly delivery systems.	**[10]**
Application of nanotechnology in drug delivery systems for respiratory diseases (Review)	This research focuses on developing nanocarrier-based drug delivery systems for effective treatment of respiratory diseases, enhancing bioavailability, targeting, and safety for inhalation therapies.	Nanotechnology shows promise for targeted respiratory disease treatment via inhaled nanoparticles, but further research is needed to improve performance, understand mechanisms, and ensure clinical safety.	**[11]**
Development of Nanotechnology-Based Drug Delivery Systems for Controlling Clinical Multidrug-Resistant	This research aims to develop biosurfactant-based nano emulsions from probiotic Bacillus to combat drug-resistant	Nanotechnology offers a promising approach against microbial biofilms and antibiotic resistance, with biosurfactant-based	

Staphylococcus aureus and Escherichia coli Associated with Aerobic Vaginitis	bacteria in aerobic vaginitis by enhancing antibiotic sensitivity and exploring antimicrobial mechanisms.	nano emulsions showing potential, though further in vivo research is needed for clinical application.	**[12]**
Revolutionizing Cancer Immunotherapy: Emerging Nanotechnology-Driven Drug Delivery Systems for Enhanced Therapeutic Efficacy	This research focuses on enhancing cancer treatment using nanotechnology-based drug delivery systems to improve drug solubility, targeting, and efficacy while reducing toxicity and overcoming tumor barriers.	Nanotechnology, particularly biosurfactant-based nano emulsions, shows strong potential against antibiotic-resistant biofilms, but further in vivo research is needed to advance their clinical application.	**[13]**
Advances in Materials Science for Precision Melanoma Therapy: Nanotechnology-Enhanced Drug Delivery Systems (Review)	This review explores nanotechnology-based drug delivery strategies for resistant melanoma, focusing on targeted, stimuli-responsive systems, theragnostic, and personalized medicine, while addressing challenges like scalability and biocompatibility.	Nanotechnology offers promising, targeted treatment for melanoma through smart, stimuli-responsive carriers and personalized approaches, though challenges like scalability and regulation remain.	**[14]**
Maytansinoids in cancer therapy: advancements in antibody–drug conjugates and nanotechnology-enhanced drug delivery systems (Review)	This review explores the therapeutic potential of maytansinoids in cancer treatment, focusing on antibody-maytansinoid conjugates (AMCs), their development, clinical success, mechanisms, and advancements for improved safety, targeting, and delivery.	Maytansinoids and their antibody conjugates show strong potential for cancer treatment, with ongoing research and nanotechnology advances aiming to enhance their safety, targeting, and clinical effectiveness.	**[15]**
Nanostructured Drug Delivery Systems in Immunotherapy: An Updated Overview of Nanotechnology-Based Therapeutic Innovations	This study explores how nanostructured drug delivery systems can enhance immunotherapy by improving targeting, uptake, and efficacy, while reviewing clinical applications and addressing current challenges.	Nanostructured drug delivery systems boost immunotherapy effectiveness, especially in cancer, but further clinical trials and interdisciplinary efforts are needed to overcome challenges like cost and safety.	**[16]**

Nanotechnology-based drug delivery for breast cancer treatment: Current applications and future directions.	Nanoparticle-based systems, including FDA-approved ones, enhance breast cancer treatment by improving targeting and overcoming resistance, with ongoing efforts focusing on AI-driven, personalized, and safer therapies.	Nanomedicine improves breast cancer treatment by enhancing drug targeting and reducing side effects, but challenges like tumor penetration, safety, and regulatory approval require further research for broader clinical use.	**[17]**
Nanotechnology: A Promising Targeted Drug Delivery System for Brain Tumours and Alzheimer's Disease.	Nanotechnology offers potential for improved diagnosis and treatment of Alzheimer's and brain cancer by enhancing drug delivery across the blood-brain barrier, though further research is needed to ensure safety and clinical efficacy	Further research is needed to ensure the safety and effectiveness of nanoparticle-based therapies for Alzheimer's and brain cancer, despite promising results in animal models and early trials.	**[18]**
An update on the advances in the field of nanostructured drug delivery systems for a variety of orthopedic applications	This study explores advancements in nanotechnology-based drug delivery systems for orthopedics, aiming to improve therapeutic efficacy through targeted, localized, and sustained drug release with reduced toxicity.	Nanotechnology shows great promise in improving orthopedic care through enhanced drug delivery and bone regeneration, but further research is needed to address safety, toxicity, and cost challenges for clinical use.	**[19]**
Novel Drug Delivery Systems as an Emerging Platform for Stomach Cancer Therapy	This review examines nanotechnology-based drug delivery advancements for stomach cancer, highlighting improved targeting, pharmacokinetics, and multifunctional nanocarriers for better diagnosis and treatment outcomes.	Nanotechnology-based drug delivery offers a promising approach to improve stomach cancer treatment by enhancing efficacy and targeting while reducing side effects, though further in vivo studies are needed for clinical use.	**[20]**
Trends in nanotechnology-based delivery systems for	This review explores psoriasis pathophysiology and therapies, highlighting	Nanotechnology improves the administration of psoriasis medications via	

dermal targeting of drugs: an enticing approach to offset psoriasis	how nanotechnology-based formulations can overcome delivery limitations to improve skin penetration, efficacy, and patient compliance.	the skin by using microscopic carriers, which lowers adverse effects and increases patient compliance and treatment efficacy.	**[21]**
Bone-Targeted Nanoparticle Drug Delivery System: An Emerging Strategy for Bone-Related Disease	This study explores nanotechnology-enhanced bone-targeted drug delivery to boost treatment efficacy, reduce side effects, and advance therapies for challenging bone disorders toward clinical application.	Nanomedicine offers targeted drug delivery for bone diseases using bone-affinitive, multifunctional nanoparticles to improve efficacy and safety, though challenges like controlled drug release remain.	**[22]**
Targeted Drug Delivery Systems for Kidney Diseases	This study highlights promising advancements in kidney-targeted nanotechnology for improved treatment efficacy and reduced toxicity, though most approaches remain in early or preclinical stages.	Kidney-targeted nanoparticles show promise, but challenges in safety, efficacy, and manufacturing persist, with biodegradable polymers like PLGA-PEG offering potential solutions for clinical use.	**[23]**

Conclusions and Research Horizons

Nanotechnology has greatly advanced a number of industries during the last fifty years, including the food, cosmetics, and pharmaceutical sectors. Along with improving food production, packaging, and safety, it has also improved medical devices such as biosensors, drug delivery systems, and imaging instruments. Despite its many advantages, increased human exposure to nanoparticles has sparked worries about their effects on the environment and human health, which has led to the development of nanotoxicology and nanomedicine. These domains evaluate nanoparticles' therapeutic potentials and hazards, including improved drug delivery, antimicrobial surfaces, and cancer cell detection. However, a major obstacle to guaranteeing safe application is still the paucity of toxicity data.

The manipulation of matter at the nanoscale (1–100 nanometers) is known as nanotechnology, and it has produced ground-breaking breakthroughs in many different sectors. It promotes miniaturization and computing in electronics and allows tailored drug administration and early disease detection in nanomedicine. Nanomaterials enhance solar cells and storage in energy systems, and they are used in clean water and pollution control technologies in the environment. Nanorobotics promises molecular-level precision in industry and health, while stronger, lighter nanocomposites are transforming materials science. The field is still growing quickly as applications spread into space exploration. However, to guarantee proper use, safety and ethical considerations are essential. All things considered, nanotechnology is changing industries, resolving world issues, and influencing the future.

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