Molecular Pathology and Biochemistry

OPEN ACCESS Freely available online

Perspective

Nanotechnology in Drug Delivery and Disease Treatment

Emily Johnson*

Department of Clinical Biochemistry, University of Toronto, Toronto, Canada.

ABOVE THE STUDY

Nanotechnology has emerged as a transformative force in drug delivery and disease treatment, offering unprecedented precision in targeting, controlled release, and therapeutic efficacy. In my opinion, it represents a crucial evolution in medicine, shifting treatment strategies from systemic, non-specific approaches toward highly localized and personalized interventions. By engineering materials at the nanoscale, researchers can design drug carriers that interact with biological systems in ways that were previously unattainable.

At the core of nanotechnology in medicine are nanoparticles structures typically ranging from 1 to 100 nanometers that can encapsulate therapeutic agents and deliver them to specific tissues or cells. These include liposomes, polymeric nanoparticles, dendrimers, metallic nanoparticles, and nanocrystals. Their small size allows them to circulate through biological barriers, while their surface properties can be modified to enhance targeting and biocompatibility. In my view, this tunability is what makes nanotechnology so powerful, as it enables the customization of drug delivery systems for different diseases and patient populations.

One of the most significant advantages of nanotechnology is targeted drug delivery. Traditional drug administration often leads to widespread distribution throughout the body, causing off-target effects and toxicity. Nanocarriers can be engineered to recognize specific cellular markers, such as receptors overexpressed on cancer cells, allowing drugs to accumulate preferentially at the disease site. This is particularly important in oncology, where minimizing damage to healthy tissues is a major challenge. Passive targeting through the Enhanced Permeability and Retention (EPR) effect, combined with active targeting via ligand-receptor interactions, has significantly improved the therapeutic index of many anticancer agents.

Controlled and sustained drug release is another key benefit of nanotechnology-based systems. By designing nanoparticles with specific physicochemical properties, drugs can be released over extended periods or in response to environmental triggers such as pH, temperature, or enzymatic activity. In my opinion, this ability to control drug kinetics at the molecular level represents a major advancement over conventional dosing regimens, which often result in fluctuating drug concentrations and reduced efficacy.

Nanotechnology also plays a crucial role in overcoming biological barriers. The Blood–Brain Barrier (BBB), for example, limits the delivery of many therapeutic agents to the central nervous system. Nanoparticles can be engineered to cross this barrier, enabling treatment of neurological disorders such as brain tumors, Alzheimer's disease, and Parkinson's disease. Similarly, nanocarriers can enhance drug absorption and stability in the gastrointestinal tract, improving oral bioavailability.

In infectious diseases, nanotechnology offers innovative solutions for both treatment and prevention. Nanoparticles can enhance the delivery of antimicrobial agents, improve vaccine efficacy, and even act as therapeutic agents themselves. For instance, lipid nanoparticle-based delivery systems have been instrumental in the development of mRNA vaccines, demonstrating the real-world impact of nanotechnology in global health.

Another promising application is in combination therapy. Nanocarriers can co-deliver multiple drugs with different mechanisms of action, ensuring synchronized delivery to target cells. This is particularly useful in diseases like cancer, where combination therapy is often required to overcome resistance. In my view, this multi-functional capability positions nanotechnology as a key platform for next-generation therapeutics.

Despite its advantages, nanotechnology in medicine faces several challenges. One major issue is safety and toxicity. The long-term effects of nanoparticles in the human body are not fully understood, and concerns remain about their accumulation in organs such as the liver and spleen. Additionally, variability in nanoparticle size, shape, and composition can influence their biological behavior, making standardization difficult.

Manufacturing and scalability also present significant hurdles. Producing nanoparticles with consistent quality and

Correspondence to: Emily Johnson, Department of Clinical Biochemistry, University of Toronto, Toronto, Canada. E-mail: emily.johnson@utoronto.ca

Received: 18-Nov-2025, Manuscript No. JMPB-25-41777; **Editor assigned:** 20-Nov-2025, PreQC No. JMPB-25-41777 (PQ); **Reviewed:** 05-Dec-2025, QC No. JMPB-25-41777; **Revised:** 11-Dec-2025, Manuscript No. JMPB-25-41777 (R); **Published:** 18-Dec-2025. DOI: 10.35248/jmpb.25.6.238.

Citation: Johnson E (2025). Nanotechnology in Drug Delivery and Disease Treatment. J Mol Pathol Biochem.6:238.

reproducibility on a large scale is technically complex and costly. Regulatory frameworks for nanomedicine are still evolving, and there is a need for clear guidelines to ensure safety and efficacy.

Another limitation is the complexity of biological systems. While targeted delivery is a major goal, achieving precise targeting in vivo is challenging due to factors such as immune clearance, protein corona formation, and heterogeneity of disease tissues. In my opinion, a deeper understanding of nano-bio interactions is essential to fully realize the potential of nanotechnology.

Looking ahead, integration of nanotechnology with other advanced fields such as gene therapy, immunotherapy, and artificial intelligence is likely to drive further innovation. Smart nanoparticles capable of sensing and responding to disease environments, as well as personalized nanomedicine tailored to individual patient profiles, are promising future directions.

In conclusion, nanotechnology offers a powerful platform for improving drug delivery and disease treatment through enhanced targeting, controlled release, and multi-functional capabilities. In my opinion, while challenges related to safety, scalability, and biological complexity remain, continued interdisciplinary research is likely to establish nanotechnology as a cornerstone of future precision medicine.