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Immune Responses to Nanoparticles: Understanding Interactions and Implications

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Abstract

The rapid development and widespread application of nanoparticles (NPs) in various fields, including medicine, industry, and consumer products, have raised concerns regarding their potential impact on the immune system. This review aims to elucidate the complex interactions between nanoparticles and the immune system, focusing on the mechanisms underlying immune responses to these engineered particles. Nanoparticles can interact with immune cells, such as macrophages, dendritic cells, and lymphocytes, leading to activation or suppression of immune responses. The physicochemical properties of nanoparticles, including size, shape, surface charge, and composition, play a crucial role in determining their immunogenicity and biocompatibility. Understanding these interactions is essential for the safe and effective design of nanoparticles for therapeutic and diagnostic applications. Moreover, the immunomodulatory effects of nanoparticles can be leveraged to develop novel strategies for targeted drug delivery, vaccine development, and immunotherapy. However, the potential adverse effects of nanoparticles on immune function, such as inflammation, autoimmunity, and hypersensitivity reactions, necessitate careful evaluation and regulation. Therefore, this review also discusses the current methodologies for assessing the immunotoxicity of nanoparticles and proposes future directions for research to ensure the safe and sustainable use of nanotechnology.

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