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Nanobiopolymers in cancer therapeutics: advancing targeted drug delivery through sustainable and controlled release mechanisms

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Nanobiopolymers have emerged as a transformative frontier in cancer treatment, leveraging nanotechnology to transform drug delivery. This review provides a comprehensive exploration of the multifaceted landscape of nano-based biopolymers, emphasizing their diverse sources, synthesis methods, and classifications. Natural, synthetic, and microbial nanobiopolymers are scrutinized, along with elucidation of their underlying mechanisms and impact on cancer drug delivery; the latest findings on their deployment as targeted drug delivery agents for cancer treatment are discussed. A detailed analysis of nanobiopolymer sources, including polysaccharides, peptides, and nucleic acids, highlights critical attributes like biodegradability, renewability, and sustainability essential for therapeutic applications. The classification of nanobiopolymers based on their origin and differentiation among natural, synthetic, and microbial sources are thoroughly examined for inherent advantages, challenges, and suitability for cancer therapeutics. The importance of targeted drug release at tumour sites, crucial for minimizing adverse effects on normal tissues, is discussed, encompassing various mechanisms. The role of polymer membrane coatings as a pivotal barrier for facilitating controlled drug release through diffusion is elucidated, providing further insight into efficient methods for cancer treatment and thus consolidating the current knowledge base for researchers and practitioners in the field of nanobiopolymers and cancer therapeutics.

1. Introduction

Cancer, a life-threatening condition characterized by uncontrolled cell growth and proliferation, remains a formidable challenge for the global healthcare system. It affects individuals across all demographics and socioeconomic statuses, imposing significant financial, emotional, and physical burdens on patients and their families.[1] The World Health Organization (WHO) identifies cancer as one of the leading global causes of death, claiming the lives of millions annually. The incidence of cancer is on a steady rise, primarily attributed to aging populations, evolving lifestyles, and environmental exposure.[2] To mitigate the impact of this disease and improve global patient outcomes, it is crucial to develop efficient and affordable cancer treatment methodologies. In recent years, scientists and researchers have explored innovative strategies to enhance the effectiveness of cancer treatment while minimizing negative effects on biological tissues.[3] Chemotherapy, radiation therapy, immunotherapy, and surgery—traditional options employed for years—have likely saved countless lives. However, these therapies exhibit intrinsic flaws that diminish their overall effectiveness.[4] Surgery, often the initial approach for localized tumours, may not be suitable for advanced or metastatic disease. Radiation therapy employs high-energy radiation to eliminate cancer cells and shrink tumours. While effective, it may inadvertently harm nearby healthy tissues and organs, resulting in negative impacts and long-term challenges.

Chemotherapy utilizes cytotoxic drugs to target cancer cells throughout the body. However, these medications can also harm healthy cells, leading to unpleasant side effects such as nausea, hair loss, and compromised immunity. Additionally, some tumours may develop resistance to chemotherapy,

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