Nanotechnology in the Life Sciences

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Nanomaterials and Environmental Biotechnology

Springer

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Nanomaterials and Environmental Biotechnology

Nanotechnology is considered as one of the emerging fields of science. It has applications in different biological and technological fields which deal with the science of materials at nanoscale (10^{-9}). On the other hand, biotechnology is another field that deals with contemporary challenges. Nanobiotechnology fills the gap between these two fields. It merges physical, chemical, and biological principles in a single realm. This combination opens up new possibilities. At nanoscale dimensions, it creates precise nanocrystals and nanoshells. Integrated nanomaterials are used with modified surface layers for compatibility with living systems, improved dissolution in water, or biorecognition leading to enhanced end results in biotechnological systems. These nanoparticles can also be hybridized with additional biocompatible substances in order to amend their qualities to inculcate novel utilities. Nanobiotechnology is used in bioconjugate chemistry by coalescing up the functionality of non-organically obtained molecular components and biological molecules in order to veil the immunogenic moieties for targeted drug delivery, bioimaging and biosensing.

This book blends the science of biology, medicine, bioinorganic chemistry, bioorganic chemistry, material and physical sciences, biomedical engineering, electrical, mechanical, and chemical science to present a comprehensive range of advancements. The development of nano-based materials has made for a greater understanding of their characterization, using techniques such as transmission electron microscope, FTIR, X-ray diffraction, scanning electron microscope EDX, and so on. This volume also highlights uses in environmental remediation, environmental biosensors and environmental protection. It also emphasizes the significance of nanobiotechnology to a series of medical applications *viz.*, diagnostics, and therapeutics stem cell technology, tissue engineering enzyme engineering, drug development and delivery. In addition this book also offers a distinctive understanding of nanobiotechnology from researchers and educators and gives a comprehensive facility for future developments and current applications of nanobiotechnology.

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Chapter 19
Nanomaterials Used for Delivery of Bioactives

Akhlesh Kumar Jain and Umesh Gupta

19.1 Introduction

Progression in genetic engineering has led to propagation of gigantic diversity of bioactives which demands effective means of carriers for intracellular delivery in order to achieve specific objectives such as selective tumor targeting, genetic vaccination, regenerative medicine, and treatment of functional loss. Generally, these biologics are prone to enzymatic degradation and deactivation. Hence, immense arrangement of efforts has been made to develop nanometric size vehicles which could not only deliver the medicaments to the desired site of action but also protect for unwanted degradation. In this regard, nanoparticles have been shown great promise as a delivery vehicle for smaller molecules, plus large bioactives, i.e., proteins, peptides, vaccines, or nucleotides by either restricted or tissue-specific delivery. In addition, formulation scientists are fascinated about nanocarriers as a delivery vehicles as proportion of quantity of surface atoms or molecules to the total count of atoms or molecules enhanced drastically hence effective surface area multiplied exponentially (Hadjipanayis et al. 2010). Further, nanoparticles are in great number and could access regions of poor access such as injured tissues, tumor cells, inflamed organs, etc. due to their tiny size (Jong and Borm 2008). Nanotechnology concentrates on encapsulating drugs in bio-friendly nanocomposites, i.e., polymeric nanoparticles, nanoliposomes, solid lipid nanoparticles, micellar systems, and bioconjugates. A schematic diagram of different varieties of nanocarriers used for delivery of bioactives is depicted in Fig. 19.1. These carriers are usually explored to enhance oral bioavailability, to sustain medicament release

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Fig. 19.1 Classification of most commonly used nanocarriers for drug delivery

in desired organ, to dissolve the therapeutics for intravascular administration, to enhance the drug stability against enzyme-mediated degradation, and to achieve targeted (cellular/organ) delivery of drugs. In addition, the release of encapsulated cargo from nanocarriers can be controlled in the organ of interest in order to produce desired therapeutic level for desired period of time to generate maximum therapeutic benefits. Usually, nanoparticles have shown greater cellular uptake compared to microparticles (Desai et al. 1996). Several important human disorder-related diseases have demonstrated significant improvement after treatment of protein-/peptide-loaded nanocarriers (Yu et al. 2016). Macromolecules have large size, high hydrophilicity and susceptibility to physical and chemical degradation, structural fragility, and complexity; hence, these characteristics strongly affect pharmacokinetic and pharmacodynamic behavior in vivo. Moreover, development processes such as higher temperature, exposure to organic solvents, etc. additionally compromise the stability of these macromolecules. To overcome all these challenges, extraordinary efforts are made to incorporate therapeutics in hydrogels, micellar systems, nanocapsules, nanoemulsions, nanoliposomes, and niosomes. Afterward, surface modification of these carriers by specific ligands was explored with an aim to deliver protein therapeutics into the organs of interest in active form. Nanomedicines approved by FDA are enlisted as per variety of carrier/material used in development of the formulation (Table 19.1). The key objective of