NANOCARRIER VACCINES

Biopharmaceutics-Based Fast Track Development

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Dedicated to the 75th year anniversary of the LM College of Pharmacy, Ahmedabad Gujarat India.

Vivek P. Chavda also wants to dedicate this book to his wife Disha and his parents

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Preface

In nanomedicine and nano-delivery systems, materials in the nanoscale range are used as diagnostic instruments or to administer therapeutic compounds to particular targeted regions in a controlled manner. By delivering precise medications to specified locations and targets, nanotechnology provides several advantages in treating chronic human illnesses. The use of nanomedicine (including chemotherapeutic medicines, biological agents, immunotherapeutic agents, etc.) in the treatment of various diseases has recently seen many notable applications. This book aims to be a single source material for understanding all the current and novel advancement in the field of nanotechnology.

Chapter 1 discusses the history and constantly evolving field of nanoparticles. Chapter 2 describes the overall composition of a nanoparticle. The next chapters explain the formulation strategy and the influencing factors in therapeutic approaches, such as vaccine development (Chapter 3), biodegradable and non-biodegradable formulation, and properties such as size, shape, charge, inertness, efficacy, morphology, and more (Chapters 4 and 5). Different nanoparticles, such as lipid-based, viral vector-based, and metal, uphold very significant properties individually, which suggests their applicability in various management tactics, as described in Chapters 6 and 7.

Chapters 8 and 9 examine how genetic information carrying entities are becoming the norm for evacuating tedious diseases. Furthermore, Chapters 10, 11, and 12 gather an exhaustive amount of information on routes of administration for the same, such as the oral route, mucosal immunity, intramuscular, subcutaneous, and intradermal. This treatment has had an astonishing effectiveness in veterinary disease management, as described in Chapter 13. Finally, Chapter 14 explores the legal regulatory for nanotechnology-based approaches.

We hope this book will help to bolster your knowledge on this vastly changing and expanding subject. Our thanks go to the prestigious Wiley and Scrivener Publishing for their continuous kind support and guidance.

Editors
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Part 1

GENERAL

1

History of Nanoparticles

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Abstract

Nanoparticles (NPs) have become a widely researched area in modern medicine due to their unique properties and potential applications. This article provides an overview of the field of NPs in healthcare, starting with a brief introduction to NPs and their history. The article then delves into modern developments in the field of NPs, including their production and various applications. It also covers the different types of NPs that have been studied, along with their properties and advantages. Furthermore, the article discusses the importance of NPs in various healthcare areas, such as drug delivery, medical imaging, and diagnostics. Finally, the article concludes with a summary of the current state of the field and the future prospects for NPs in healthcare. Understanding the properties and potential applications of NPs can contribute to the development of innovative medical therapies and advance the field of healthcare.

***Keywords*:** Nanoparticles, history, medical imaging, diagnosis, future prospects

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1.1 Introduction

Nanoparticles (NPs) have emerged as a potential research area in nanotechnology that frequently appears in materials science, biomedical engineering, and nanomedicine sectors. A NP is the fundamental unit in the fabrication of a nanostructure with one or more nanometric dimensions ranging in size that may differ from the bulk material. The word "nano" represents a nanometer (nm, 10^{-9} m), an International System of Unit for length. In principle, NPs are materials with lengths ranging from 1 to 100 nm. There are numerous examples from ancient times where nanostructures or NPs have been used for various purposes. The varieties of glorious colors of glass windows of medieval cathedrals are an ancient witness to the utilization of metal oxide NPs [1]. NPs evolved in different eras and from different regions such as hand stencils of Sulawesi cave in Indonesia and hair dyes with lead sulfide NPs in Egypt. Mesopotamia and Egypt produced glassware using inorganic NPs in the fourteenth century BC [2].

The different types of NP classifications, functionalization techniques, various types of synthesis approaches, and growth-related mechanisms are evolved. NPs may be classified into various groups related to dimensionality space; morphology major groups are organic polymeric NPs, inorganic NPs, ceramic NPs, and bionanoparticles [3]. NPs can be synthesized either from a simple material or using a range of multiple composite objects. The synthesis methods of NM are generally classified into "top–down" and "bottom–up" approaches. In the top–down approach, a solid material is broken into smaller particles by external forces, while in the bottom–up approach, nanostructures are synthesized through the buildup of molecules or atoms. These synthetic approaches can be further differentiated by chemical, physical, and biological processes that, through improvement over time, also emerged as including mechanochemical and physiochemical processes. In the current scenario, tremendous metallic nanomaterials are being synthesized in bulk using titanium, copper, zinc, magnesium, alginate, aluminum oxide, silica, gold, and silver.

NPs are widely used to improve the pharmaceutical properties of medicines including penetration, plasma distribution, half-life, and target site accumulation. Size, shape, charge, and elasticity are physical properties of NPs and play a role to provide desired pharmacokinetic properties for implementation in drug delivery systems. Mechanical properties of NPs include elasticity; these overcome biological barriers from the site of application to the site of solid tumor and provide superior cancer drug delivery [4]. NPs have diverted physical and chemical characteristics from bulk material and show a wide range of applications in a multitude of fields, such as medical treatments; use in various industry departments; the manufacture of oxide fuel; and solar batteries for energy storage, cosmetics, and clothes. Nanotechnology can also enhance the properties of construction materials, where recycling concrete with NPs support sustainability [5]. Nanotechnology-based products used for the control of disease in the healthcare system are referred to as "nanomedicine." In recent years, nano-sized compounds such as liposomes, polymers, and virus-sized NPs become attractive development as targeted delivery vehicles for viral antigens. NPs provide similar size distribution as the viruses and therefore NPs loaded with viral antigens can enter the virus-targeted cells. In recent years, the utilization of NPs has also expanded toward vaccine delivery with high bioavailability, elevated immunogenicity, and controlled release profiles [6].

1.2 History of Nanoparticles

Although NPs have been studied for centuries, the term was not coined until the late 1970s. In 1959, Nobel Prize–winning American physicist Richard Feynman proposed the concept of nanotechnology. "There's Plenty of Space at the Bottom" was the title of a lecture Feynman gave at the California Institute of Technology at the American Physical Society's annual meeting (Caltech). The question "Why can't we write the full 24 volumes of the Encyclopaedia Britannica on the head of a pin?" was posed by Feynman in this lecture, and he also sketched out a vision of utilizing machines to build smaller machines all the way down to the molecular level [7]. Refer to Figure 1.1.

Feynman's position as the father of modern nanotechnology was finally cemented by the validation of the ground-breaking idea he offered. Approximately 15 years later, in 1974, Japanese scientist Norio Taniguchi used the word "nanotechnology" for the first time. He defined nanotechnology as the manipulation of materials at the atomic or molecular scale by procedures like separation, consolidation, and deformation [8].

NPs have been utilized for centuries before Feynman put forward the concept of nanotechnology. More than 4,500 years ago, humans used natural asbestos nanofibers to reinforce ceramic matrix materials. More than 4,000 years ago, the ancient Egyptians used nanomaterials (NM) as well. They produced PbS NPs with a diameter of about 5 nm for use in hair dye. When Egyptians and Mesopotamians began employing metals to make

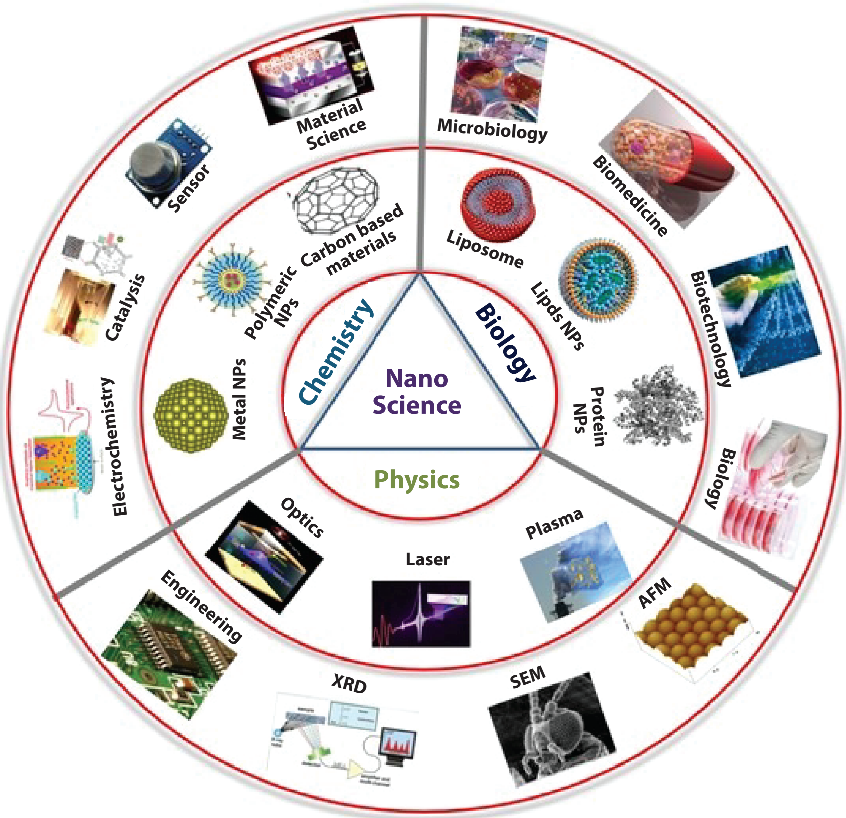

Figure 1.1 The evaluation of NPs on the basis of broad terms including chemistry, biology, and physics. Adopted under CC BY 4 from [8].

glass in the 14th and 13th centuries BC, it may be said that the period of metallic NPs began. Since then, metallic NPs have been synthesized via chemical processes. One of the most intriguing examples of nanotechnology in the ancient world was presented by the Romans in the fourth century AD, who employed NPs and structures. Yet, the most well-known use of ancient metallic NPs is on a piece of Roman glass. The Lycurgus cups are dichroic glass cups from the fourth century AD that show different colors depending on the direction of the light: red when it comes from behind and green when it comes from the front. To understand the dichroism phenomena, scientists examined the cup in 1990 using a transmission electron microscope. The presence of NPs with a diameter of 50–100 nm is what causes the dichroism (two colors) that has been seen. These NPs were identified by X-ray analysis as silver–gold (Ag-Au) alloy with an Ag:Au ratio of