# CHAPTER 1
# INTRODUCTION OF NANOMATERIALS FOR BIOMEDICAL APPLICATIONS

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## 1.1 INTRODUCTION

Over the past few decades, the field of nanotechnology has significantly revolutionised industries around the world. In general, the prefix '*nano*' denotes one billionth ($10^{-9}$) of any given parameter. At the same time, nanotechnology refers to the science and engineering field that involves designing, producing, and manipulating systems at the nanoscale level, working with atoms and molecules. This technology has promised scientific advancements in various sectors such as energy, materials, manufacturing, storage, consumer products, and, most recently, medicine (Malik et al., 2023).

In medicine or biomedicine, nanotechnologies have demonstrated their benefits across various specialities, including medical treatments such as antimicrobial therapy, cancer treatment, drug delivery, and the development of nanomaterials for biomedical applications (Haleem et al., 2023). This book focuses mostly on the application of nanomaterials in biomedical applications. For example, various nanomaterials, such as metallic nanoparticles, carbon-based materials, dendrimers, and polymers, have been reported in developing antimicrobials, anticancer treatments, drug delivery, and immunotherapy. Nanotechnology also

involves designing, arranging, and applying structures, devices, and systems by manipulating the shape and size of particles within nanomaterials, including nanoparticles (NPs). Therefore, nanotechnology is advancing various critical applications that span across natural sciences to biomedical fields (Haleem et al., 2023). Although nanomaterials have shown great potential in the field of biomedicine, there is currently a lack of regulatory guidance in this area, which is important for providing legal certainty to manufacturers, policymakers, health authorities, and the public. Therefore, the regulations of nanomaterials for clinical applications are also discussed in this book. Moreover, since nanomaterials are expected to significantly impact biomedical fields, their future directions are also discussed in this book to highlight the current trends for the reader.

The book is divided into 8 chapters. It begins with Chapter 1 as an introductory chapter, followed by Chapters 2 through 6, which discuss the preparation, various applications, and nanotoxicity of nanomaterials. The final two chapters (Chapters 7 and 8) briefly discuss the regulatory standards, grand challenges, and future directions of nanomaterials in the biomedical field (Figure 1.1).

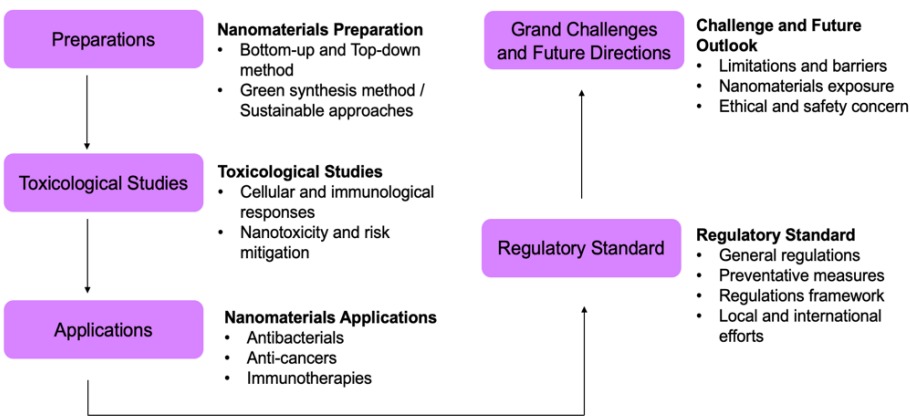


**Figure 1.1** Current applications of nanomaterials in biomedical applications

Chapter 2 provides the preparation of nanomaterials via various sustainable approaches, which are recommended by the United Nations through its sustainable development goals (SDGs). As the application of nanomaterials is solely focused on the biomedical field, toxicological studies are required before applying them in a clinical setting. Hence, Chapter 3 particularly enlightens the toxicity issues related to nanomaterials in order to bridge the knowledge gap and address these issues.

The applications of nanomaterials in the biomedical field are discussed in Chapters 4 through 6. Chapter 4 discusses how nanomaterials can be applied as anti-cancer agents and immunotherapies, while Chapter 5 discusses their antibacterial applications. The molecular pathways of nanomaterials in cancer treatment are discussed in Chapter 6. This chapter emphasises the key regulatory pathways that play essential roles in the regulation of signal transduction and biological processes such as cell proliferation, apoptosis, and metabolism.

On the other hand, Chapter 7 particularly emphasises the regulation of nanomaterials. Its comprehensive discussion on regulatory guidelines, decisions, and laws issued by major organisations such as the U.S. Environmental Protection Agency, the United States Food and Drug Administration (U.S. FDA), and the Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) provides insight into the policies and standards for the use of nanomaterials in clinical settings. The final chapter, Chapter 8, provides discussions on the limitations, barriers, and challenges, as well as the future directions of nanomaterials in the biomedical field. These insights provide useful information for understanding risk assessment, safety measures, and protocols to ensure the safe and effective use of nanomedical technologies in healthcare and society as a whole. In essence, this book interlaces the chapters, providing a current overview of exciting developments in using nanomaterials for biomedical applications, addressing the limitations and challenges to achieve the desired goal of improving healthcare efficiency.