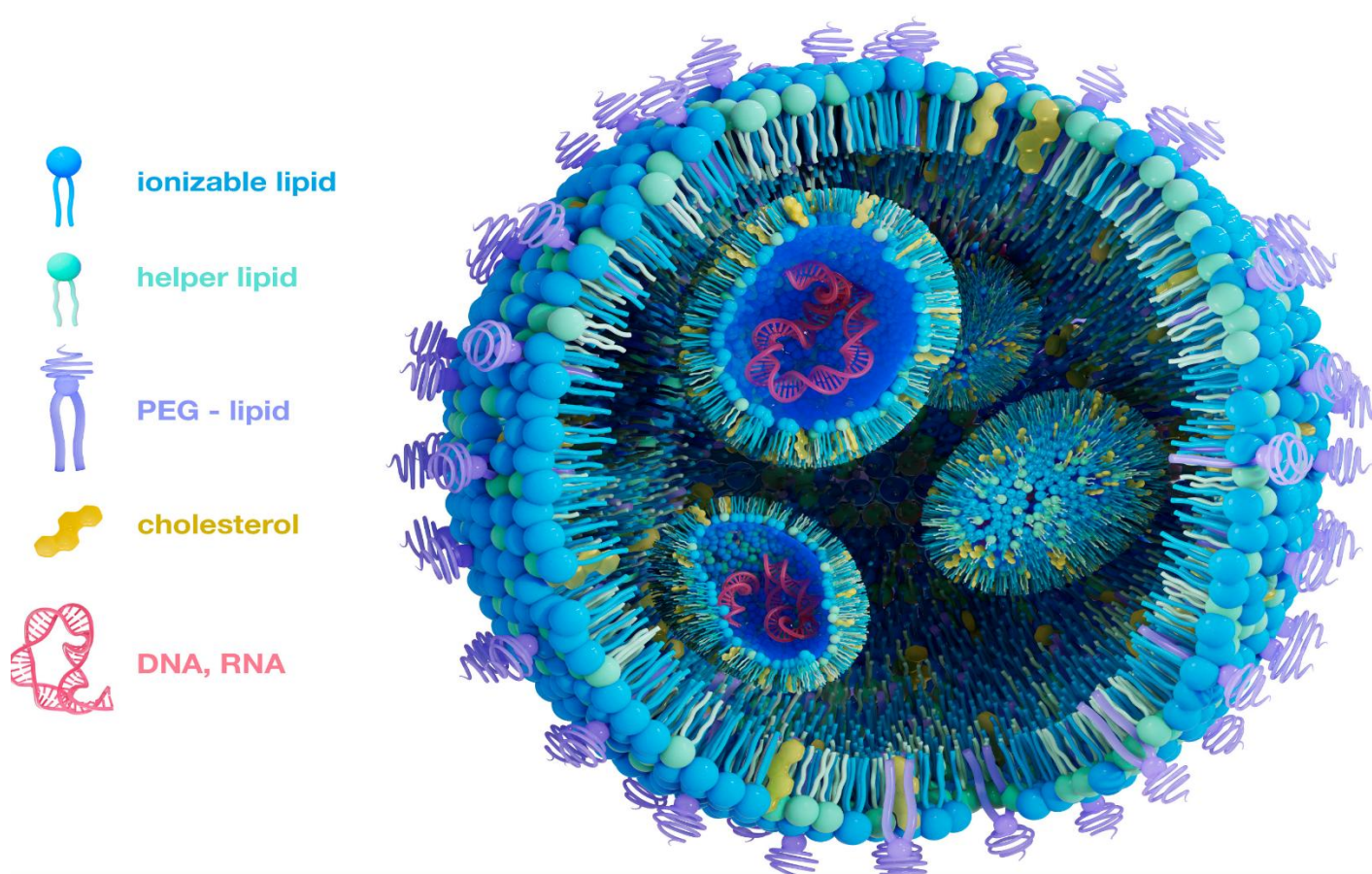


ADVANCES IN PHARMACEUTICAL NANOTECHNOLOGY AND DRUG DELIVERY



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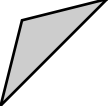
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DEDICATION

This book is dedicated to all researchers, academicians, healthcare professionals, and students whose relentless pursuit of scientific excellence continues to advance the field of pharmaceutical nanotechnology. Their dedication to innovation, research, and patient-centered healthcare inspires the development of safer, smarter, and more effective drug delivery systems for the benefit of society.



FOREWORD

Nanotechnology has emerged as one of the most promising and transformative areas of modern pharmaceutical sciences. The development of nanoscale drug delivery systems has created new opportunities to overcome several limitations associated with conventional drug delivery, including poor solubility, inadequate bioavailability, instability, uncontrolled drug release, and difficulty in achieving targeted delivery. *Advances in Pharmaceutical Nanotechnology and Drug Delivery* brings together a range of contemporary topics that reflect the growing importance of nanotechnology in pharmaceutical research and therapeutic development. The volume encompasses polymeric nanoparticles, oral nanocarriers, transdermal delivery, nasal and ocular delivery, blood–brain barrier crossing systems, vesicular carriers, and combination drug delivery approaches. The book also addresses important formulation considerations, including the selection of nanocarriers according to drug properties and the role of excipients in nanocarrier formulation. These aspects are essential for understanding the relationship between drug characteristics, formulation design, nanocarrier performance, and therapeutic outcomes. An important feature of this volume is its multidisciplinary coverage. Contributions from researchers and academicians associated with different pharmaceutical institutions provide varied perspectives on the design, development, and application of nanotechnology-based delivery systems. The inclusion of emerging applications in areas such as central nervous system disorders and metabolic and endocrine disorders further demonstrates the expanding therapeutic potential of pharmaceutical nanotechnology. This volume will be valuable to undergraduate and postgraduate students, research scholars, academicians, pharmaceutical scientists, formulation researchers, and professionals interested in advanced drug delivery technologies.

I congratulate the editors and all contributing authors for their efforts in bringing together this informative volume. I hope this book serves as a useful academic resource and encourages further research and innovation in pharmaceutical nanotechnology and drug delivery.

PREFACE

The continuous development of effective and patient-oriented drug delivery systems is an important objective of pharmaceutical research. Although conventional dosage forms have contributed significantly to modern healthcare, several therapeutic agents continue to face challenges such as poor aqueous solubility, low bioavailability, instability, rapid degradation, undesirable distribution, and limited ability to reach specific biological sites. Nanotechnology has emerged as a powerful approach for addressing many of these challenges. By engineering drug delivery systems at the nanoscale, researchers can explore improved drug encapsulation, controlled release, enhanced bioavailability, site-specific delivery, and improved therapeutic performance. The present volume, **Advances in Pharmaceutical Nanotechnology and Drug Delivery**, has been developed to provide readers with an overview of selected emerging concepts and applications in this rapidly evolving field. The book covers a broad range of topics beginning with polymeric nanoparticles and nanocarriers for oral drug delivery. It further discusses the selection of nanocarriers based on drug properties and the role of excipients in nanocarrier formulation, providing important insights into the formulation and development of nanoscale delivery systems. Several chapters focus on route-specific applications, including transdermal, nasal, ocular, and oral drug delivery. Special attention is also given to nanocarriers capable of crossing the blood–brain barrier for central nervous system drug delivery, an area of considerable research interest due to the complex physiological barriers associated with brain drug delivery. The volume additionally discusses niosomes and transferosomes as novel vesicular systems, combination drug delivery using nanocarriers, and emerging nanotherapeutic approaches for metabolic and endocrine disorders. Together, these topics demonstrate the broad applicability of nanotechnology across different therapeutic and pharmaceutical challenges. The contributors represent diverse academic and research backgrounds, bringing together perspectives from pharmaceutical technology, pharmaceuticals, drug delivery, and related areas. The book is intended to support students, research scholars, academicians, pharmaceutical scientists, and professionals seeking an accessible overview of current developments in pharmaceutical nanotechnology.

We hope that **Advances in Pharmaceutical Nanotechnology and Drug Delivery** will serve as a useful reference for academic learning and research and will encourage readers to explore innovative approaches for the development of safer, more effective, and more targeted drug delivery systems.

ABOUT THE BOOK

Nanotechnology has become an important area of modern pharmaceutical research, providing innovative platforms for the design and development of advanced drug delivery systems. Nanoscale carriers offer considerable potential for improving drug solubility, stability, bioavailability, controlled release, targeting, and therapeutic effectiveness. *Advances in Pharmaceutical Nanotechnology and Drug Delivery* presents a comprehensive collection of chapters covering important concepts, emerging technologies, formulation considerations, and therapeutic applications of pharmaceutical nanotechnology. The volume includes discussions on polymeric nanoparticles, oral nanocarriers, nanocarrier selection based on drug properties, transdermal drug delivery, and the role of excipients in nanocarrier formulation. These topics provide a foundation for understanding the principals involved in the development and optimization of nanocarrier-based formulations. The book also explores specialized delivery approaches, including blood–brain barrier crossing nanocarriers for central nervous system drug delivery, niosomes and transferosomes, nasal drug delivery, ocular drug delivery, and combination drug delivery using nanocarriers. In addition, the volume highlights the emerging application of nanotherapeutics in metabolic and endocrine disorders, reflecting the expanding role of nanotechnology beyond conventional drug delivery applications. By bringing together contributions from researchers and academicians associated with different pharmaceutical institutions, the book provides diverse perspectives on the formulation, selection, development, and application of nanocarrier-based systems. This book is particularly useful for B.Pharm and M.Pharm students, research scholars, teachers, academicians, pharmaceutical scientists, formulation researchers, and industry professionals interested in pharmaceuticals, pharmaceutical technology, nanotechnology, and advanced drug delivery.

The volume aims to bridge fundamental pharmaceutical concepts with emerging research applications and provide readers with a contemporary understanding of the opportunities and challenges associated with nanotechnology-based drug delivery.

MESSAGE FROM THE EDITORS

It is our pleasure to present *Advances in Pharmaceutical Nanotechnology and Drug Delivery*, an edited volume dedicated to the rapidly developing field of pharmaceutical nanotechnology and its applications in modern drug delivery. The field of drug delivery has undergone significant transformation with the introduction of nanoscale technologies. Nanocarriers have provided researchers with new possibilities for addressing challenges associated with conventional dosage forms, including poor drug solubility, limited bioavailability, premature degradation, uncontrolled release, and difficulties associated with delivery to specific biological sites. With this volume, we have attempted to bring together selected topics that represent both fundamental concepts and emerging applications of nanotechnology in pharmaceutical sciences. The chapters cover polymeric nanoparticles, oral nanocarriers, nanocarrier selection according to drug properties, transdermal delivery, excipient considerations, and several specialized delivery approaches. Particular emphasis has been placed on challenging routes and therapeutic areas, including central nervous system drug delivery through blood–brain barrier crossing nanocarriers, ocular delivery, nasal delivery, and transdermal delivery. The volume also discusses niosomes and transferosomes, combination drug delivery using nanocarriers, and emerging nanotherapeutic approaches for metabolic and endocrine disorders. We believe that the multidisciplinary nature of these contributions reflects the broad scope of pharmaceutical nanotechnology. The knowledge presented in this volume can help students understand fundamental concepts, assist research scholars in identifying emerging research directions, and provide academicians and pharmaceutical professionals with a useful reference to contemporary developments. We sincerely appreciate the efforts of all contributing authors for sharing their knowledge and expertise. We are equally grateful to everyone involved in the editorial, review, formatting, and publication processes that helped bring this volume together. It is our hope that *Advances in Pharmaceutical Nanotechnology and Drug Delivery* will contribute to academic learning, stimulate scientific discussion, and encourage further research toward innovative, effective, safe, and patient-oriented drug delivery systems.

With best wishes,

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9 COMBINATION DRUG DELIVERY USING NANOCARRIERS

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ABSTRACT

Combination drug delivery using nanocarriers is an emerging approach designed to improve the efficacy and safety of drug therapy. In many diseases, especially cancer and infectious disorders, the use of more than one drug is required to achieve better therapeutic effects. However, different drugs may have different solubility, stability, absorption, and distribution properties, making their combined delivery challenging. Nanocarriers provide an effective platform for overcoming these limitations by carrying two or more drugs within the same delivery system and releasing them at the desired sites. Various nanocarriers, including liposomes, polymeric nanoparticles, lipid nanoparticles, micelles, dendrimers, nanogels, and hybrid systems, have been investigated for combination therapies. These systems can improve drug solubility, protect drugs from premature degradation, enhance cellular uptake, and provide controlled or sustained drug release. Targeting strategies can further increase drug accumulation in diseased tissues and reduce unwanted exposure to healthy ones. An important advantage of combination nanocarriers is their ability to maintain a suitable ratio of different drugs, which may enhance synergistic activity and reduce drug resistance. Despite these benefits, several challenges remain, including formulation stability, drug compatibility, reproducible drug loading, toxicity, large-scale manufacturing, and regulatory approvals. Recent advances in nanotechnology and biomaterials have provided new opportunities for developing safer and more effective combination delivery systems. This chapter discusses the basic concepts, major types of nanocarriers, formulation approaches, mechanisms of drug co-delivery, therapeutic applications, current challenges, and future prospects of combination drug delivery using nanocarriers.

Keywords: combination drug delivery, nanocarriers, co-delivery, liposomes, targeted delivery, and controlled release.

9.1 INTRODUCTION

Modern drug therapy has improved the treatment of many diseases; however, the use of a single drug is not always sufficient to achieve the desired therapeutic response. Many diseases involve several biological pathways that may change over time, making treatment more complex. In such situations, the use of two or more drugs with different or complementary mechanisms of action can provide better therapeutic outcomes.(1) Combination drug therapy has therefore become an important approach in the management of cancer, infectious diseases, inflammatory disorders, cardiovascular diseases, and several other chronic conditions. However, administering multiple drugs together also creates challenges related to their solubility, stability, pharmacokinetics, distribution, toxicity, and delivery to the target site. These limitations have encouraged the development of advanced drug delivery systems that can transport different therapeutic agents in a controlled and coordinated manner. Among these approaches, nanocarrier-based combination drug delivery has received considerable attention because of its ability to improve drug stability, targeting, cellular uptake, and controlled release.(2)