

METHODS IN MOLECULAR BIOLOGY

Series Editor
John M. Walker
School of Life Sciences
University of Hertfordshire
Hatfield, Hertfordshire, AL10 9AB, UK

For further volumes:
<http://www.springer.com/series/7651>

Drug Delivery System

Second Edition

Edited by

Kewal K. Jain

Jain PharmaBiotech, Basel, Switzerland

 **Humana Press**

Editor

Kewal K. Jain
Jain PharmaBiotech
Basel, Switzerland

ISSN 1064-3745 ISSN 1940-6029 (electronic)
ISBN 978-1-4939-0362-7 ISBN 978-1-4939-0363-4 (eBook)
DOI 10.1007/978-1-4939-0363-4
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2014931849

© Springer Science+Business Media New York 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Humana Press is a brand of Springer
Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Several new technologies for drug delivery have been developed since the publication of the first edition of this book 5 years ago. Some of these are described in the second edition in the style that has led to the popularity of “Methods in Molecular Biology” series. The overview chapter has been updated to include references to new methods including those that are described in this book. Some of the novel methods of drug delivery are published here for the first time. There is an increase in the refinement and use of nanobiotechnology techniques for drug delivery, which form the basis of 6 of the 15 techniques described. Most of the methods are experimental and used in laboratories, but one method in clinical use for the intrathecal delivery of analgesics is described in detail. It is hoped that this book will continue to be useful for pharmaceutical scientists as well as physicians both in the academic institutions and in the industry.

Basel, Switzerland

Kewal K. Jain, M.D.

Contents

<i>Preface</i>	<i>v</i>
<i>Contributors</i>	<i>ix</i>
1 Current Status and Future Prospects of Drug Delivery Systems	1
<i>Kewal K. Jain</i>	
2 A Method for Screening Mitochondrial Fusogenic Envelopes for Use in Mitochondrial Drug Delivery	57
<i>Yuma Yamada and Hideyoshi Harashima</i>	
3 Ultrasound-Directed, Site-Specific Gene Delivery	67
<i>Jason Castle and Steven B. Feinstein</i>	
4 Synthesis of Thermoresponsive Polymers for Drug Delivery.	77
<i>Sushil Mishra, Arnab De, and Subho Mozumdar</i>	
5 Recombinant Stem Cells as Carriers for Cancer Gene Therapy.	103
<i>Yu-Lan Hu and Jian-Qing Gao</i>	
6 Microfluidic-Based Manufacture of siRNA-Lipid Nanoparticles for Therapeutic Applications	109
<i>Colin Walsh, Kevin Ou, Nathan M. Belliveau, Tim J. Leaver, Andre W. Wild, Jens Huft, Paulo J. Lin, Sam Chen, Alex K. Leung, Justin B. Lee, Carl L. Hansen, Robert J. Taylor, Euan C. Ramsay, and Pieter R. Cullis</i>	
7 Microneedle-Iontophoresis Combinations for Enhanced Transdermal Drug Delivery.	121
<i>Ryan F. Donnelly, Martin J. Garland, and Ahlam Zaid Alkilani</i>	
8 Polymer Nanoparticle-Based Controlled Pulmonary Drug Delivery.	133
<i>Moritz Beck-Broichsitter, Alexandra C. Dalla-Bona, Thomas Kissel, Werner Seeger, and Thomas Schmechl</i>	
9 Antibody Labeling with Radioiodine and Radiometals.	147
<i>Suprit Gupta, Surinder Batra, and Maneesh Jain</i>	
10 Self-Assembling Peptide-Based Delivery of Therapeutics for Myocardial Infarction	159
<i>Archana V. Boopathy and Michael E. Davis</i>	
11 Applications of Chitosan Nanoparticles in Drug Delivery.	165
<i>H.A. Tajmir-Riahi, Sh. Nafisi, S. Sanyakamdhorn, D. Agudelo, and P. Chanphai</i>	
12 A Method for Evaluating Nanoparticle Transport Through the Blood–Brain Barrier In Vitro.	185
<i>Daniela Guarnieri, Ornella Muscetti, and Paolo A. Netti</i>	

13	Bacterial Systems for Gene Delivery to Systemic Tumors	201
	<i>Joanne Cummins, Michelle Cronin, Jan Peter van Pijkeren, Cormac G.M. Gahan, and Mark Tangney</i>	
14	Synthesis of a Smart Nanovehicle for Targeting Liver	211
	<i>Arnab De, Sushil Mishra, Seema Garg, and Subho Mozumdar</i>	
15	Intranasal Delivery of Chitosan–siRNA Nanoparticle Formulation to the Brain	233
	<i>Meenakshi Malhotra, Catherine Tomaro-Duchesneau, Shyamali Saha, and Satya Prakash</i>	
16	Intrathecal Delivery of Analgesics	249
	<i>Jose De Andres, Juan Marcos Asensio-Samper, and Gustavo Fabregat-Cid</i>	
	<i>Index</i>	279

Contributors

- D. AGUDELO • *Department of Chemistry–Physics, University of Québec at Trois-Rivières, Trois-Rivières, QC, Canada*
- AHLAM ZAID ALKILANI • *Medical Biology Centre, School of Pharmacy, Queen’s University Belfast, Belfast, UK*
- JUAN MARCOS ASENSIO-SAMPER • *Multidisciplinary Pain Management Department, Valencia University General Hospital, Valencia, Spain; Department of Anesthesia, Valencia University General Hospital, Valencia, Spain*
- SURINDER BATRA • *Department of Biochemistry and Molecular Biology, College of Medicine, University of Nebraska Medical Center, Omaha, NE, USA; Eppley Institute for Research in Cancer and Allied Diseases, University of Nebraska Medical Center, Omaha, NE, USA; Buffet Cancer Center, Omaha, NE, USA*
- MORITZ BECK-BROICHSITTER • *Faculté de Pharmacie, Institut Galien, Université Paris-Sud, Châtenay-Malabry, France; Department of Internal Medicine, Medical Clinic II, Justus-Liebig-Universität, Giessen, Germany*
- NATHAN M. BELLIVEAU • *Precision NanoSystems Inc., Vancouver, BC, Canada*
- ARCHANA V. BOOPATHY • *Wallace H. Coulter Department of Biomedical Engineering, Emory University and Georgia Institute of Technology, Atlanta, GA, USA*
- JASON CASTLE • *GE Global Research Niskayuna, Schenectady, NY, USA*
- P. CHANPHAI • *Department of Chemistry–Physics, University of Québec at Trois-Rivières, Trois-Rivières, QC, Canada*
- SAM CHEN • *University of British Columbia, Vancouver, Vancouver, BC, Canada*
- MICHELLE CRONIN • *Cork Cancer Research Centre, BioSciences Institute, University College Cork, Cork, Ireland*
- PIETER R. CULLIS • *University of British Columbia, Vancouver, Vancouver, BC, Canada; Precision NanoSystems Inc., Vancouver, Vancouver, BC, Canada*
- JOANNE CUMMINS • *Cork Cancer Research Centre, BioSciences Institute, University College Cork, Cork, Ireland*
- ALEXANDRA C. DALLA-BONA • *Department of Internal Medicine, Medical Clinic II, Justus-Liebig-Universität, Giessen, Germany*
- MICHAEL E. DAVIS • *Wallace H. Coulter Department of Biomedical Engineering, Emory University and Georgia Institute of Technology, Atlanta, GA, USA*
- ARNAB DE • *Department of Microbiology and Immunology, Columbia University, New York, NY, USA*
- JOSE DE ANDRES • *Multidisciplinary Pain Management Department, Valencia University General Hospital, Valencia, Spain; Department of Anesthesia, Valencia University General Hospital, Valencia, Spain*
- RYAN F. DONNELLY • *Medical Biology Centre, School of Pharmacy, Queen’s University Belfast, Belfast, UK*

- GUSTAVO FABREGAT-CID • *Multidisciplinary Pain Management Department, Valencia University General Hospital, Valencia, Spain; Department of Anesthesia, Valencia University General Hospital, Valencia, Spain*
- STEVEN B. FEINSTEIN • *Rush University medical Center, Chicago, IL, USA*
- CORMAC G.M. GAHAN • *Department of Microbiology and Alimentary Pharmabiotic Centre, University College Cork, Cork, Ireland; School of Pharmacy, University College Cork, Cork, Ireland*
- JIAN-QING GAO • *Institute of Pharmaceutics, College of Pharmaceutical Sciences, Zhejiang University, Hangzhou, Zhejiang, P.R. China*
- SEEMA GARG • *Department of Chemistry, University of Delhi, Delhi, India*
- MARTIN J. GARLAND • *Medical Biology Centre, School of Pharmacy, Queen's University Belfast, Belfast, UK*
- DANIELA GUARNIERI • *Center for Advanced Biomaterials for Health Care@CRIB, Italian Institute of Technology, IIT, Naples, Italy*
- SUPRIT GUPTA • *Department of Biochemistry and Molecular Biology, College of Medicine, University of Nebraska Medical Center, Omaha, NE, USA*
- CARL L. HANSEN • *University of British Columbia, Vancouver, Vancouver, BC, Canada; Precision NanoSystems Inc., Vancouver, Vancouver, BC, Canada*
- HIDEYOSHI HARASHIMA • *Laboratory for Molecular Design of Pharmaceutics, Faculty of Pharmaceutical Sciences, Hokkaido University, Sapporo, Japan*
- YU-LAN HU • *Institute of Pharmaceutics, College of Pharmaceutical Sciences, Zhejiang University, Hangzhou, Zhejiang, P.R. China*
- JENS HUFT • *University of British Columbia, Vancouver, BC, Canada*
- KEWAL K. JAIN • *Jain PharmaBiotech, Basel, Switzerland*
- MANEESH JAIN • *Department of Biochemistry and Molecular Biology, College of Medicine, University of Nebraska Medical Center, Omaha, NE, USA*
- THOMAS KISSEL • *Department of Pharmaceutics and Biopharmacy, Philipps-Universität, Marburg, Germany*
- TIM J. LEAVER • *Precision NanoSystems Inc., Vancouver, BC, Canada*
- JUSTIN B. LEE • *University of British Columbia, Vancouver, Vancouver, BC, Canada*
- ALEX K. LEUNG • *University of British Columbia, Vancouver, Vancouver, BC, Canada*
- PAULO J. LIN • *University of British Columbia, Vancouver, Vancouver, BC, Canada*
- MEENAKSHI MALHOTRA • *Pharmacodelivery Group, School of Pharmacy, University College Cork, Cork, Ireland; Biomedical Technology and Cell Therapy Research Laboratory, Departments of Biomedical Engineering, Faculty of Medicine, McGill University, Montreal, QC, Canada*
- SUSHIL MISHRA • *Department of Chemistry, University of Delhi, Delhi, India*
- SUBHO MOZUMDAR • *Department of Chemistry, University of Delhi, Delhi, India*
- ORNELLA MUSCETTI • *Center for Advanced Biomaterials for Health Care@CRIB and Interdisciplinary Research Centre on Biomaterials (CRIB), Italian Institute of Technology, IIT and University of Naples Federico II, Naples, Italy*
- SH. NAFISI • *Department of Chemistry, San Jose State University, San Jose, CA, USA*
- PAOLO A. NETTI • *Center for Advanced Biomaterials for Health Care@CRIB and Interdisciplinary Research Centre on Biomaterials (CRIB), Italian Institute of Technology, IIT and University of Naples Federico II, Naples, Italy*
- KEVIN OU • *University of British Columbia, Vancouver, BC, Canada*
- SATYA PRAKASH • *Biomedical Technology and Cell Therapy Research Laboratory, Department of Biomedical Engineering, Faculty of Medicine, McGill University, Montreal, QC, Canada*

- EUAN C. RAMSAY • *University of British Columbia, Vancouver, Vancouver, BC, Canada; Precision NanoSystems Inc., Vancouver, Vancouver, BC, Canada*
- SHYAMALI SAHA • *Biomedical Technology and Cell Therapy Research Laboratory, Department of Biomedical Engineering, Faculty of Medicine, McGill University, Montreal, QC, Canada; Faculty of Dentistry, McGill University, Montreal, QC, Canada*
- S. SANYAKAMDHORN • *Department of Chemistry–Physics, University of Québec at Trois-Rivières, Trois-Rivières, QC, Canada*
- THOMAS SCHMEHL • *Department of Internal Medicine, Medical Clinic II, Justus-Liebig-Universität, Giessen, Germany*
- WERNER SEEGER • *Department of Internal Medicine, Medical Clinic II, Justus-Liebig-Universität, Giessen, Germany*
- H.A. TAJMIR-RIAHI • *Department of Chemistry–Physics, University of Québec at Trois-Rivières, Trois-Rivières, QC, Canada*
- MARK TANGNEY • *Cancer Research Centre, BioSciences Institute, University College Cork, Cork, Ireland*
- ROBERT J. TAYLOR • *Precision NanoSystems Inc., Vancouver, Vancouver, BC, Canada*
- CATHERINE TOMARO-DUCHESNEAU • *Biomedical Technology and Cell Therapy Research Laboratory, Department of Biomedical Engineering, Faculty of Medicine, McGill University, Montreal, QC, Canada*
- JAN PETER VAN PIJKEREN • *Department of Microbiology and Molecular Genetics, Michigan State University, East Lansing, MI, USA*
- COLIN WALSH • *University of British Columbia, Vancouver, BC, Canada*
- ANDRE W. WILD • *University of British Columbia, Vancouver, BC, Canada*
- YUMA YAMADA • *Laboratory for Molecular Design of Pharmaceuticals, Faculty of Pharmaceutical Sciences, Hokkaido University, Sapporo, Japan*