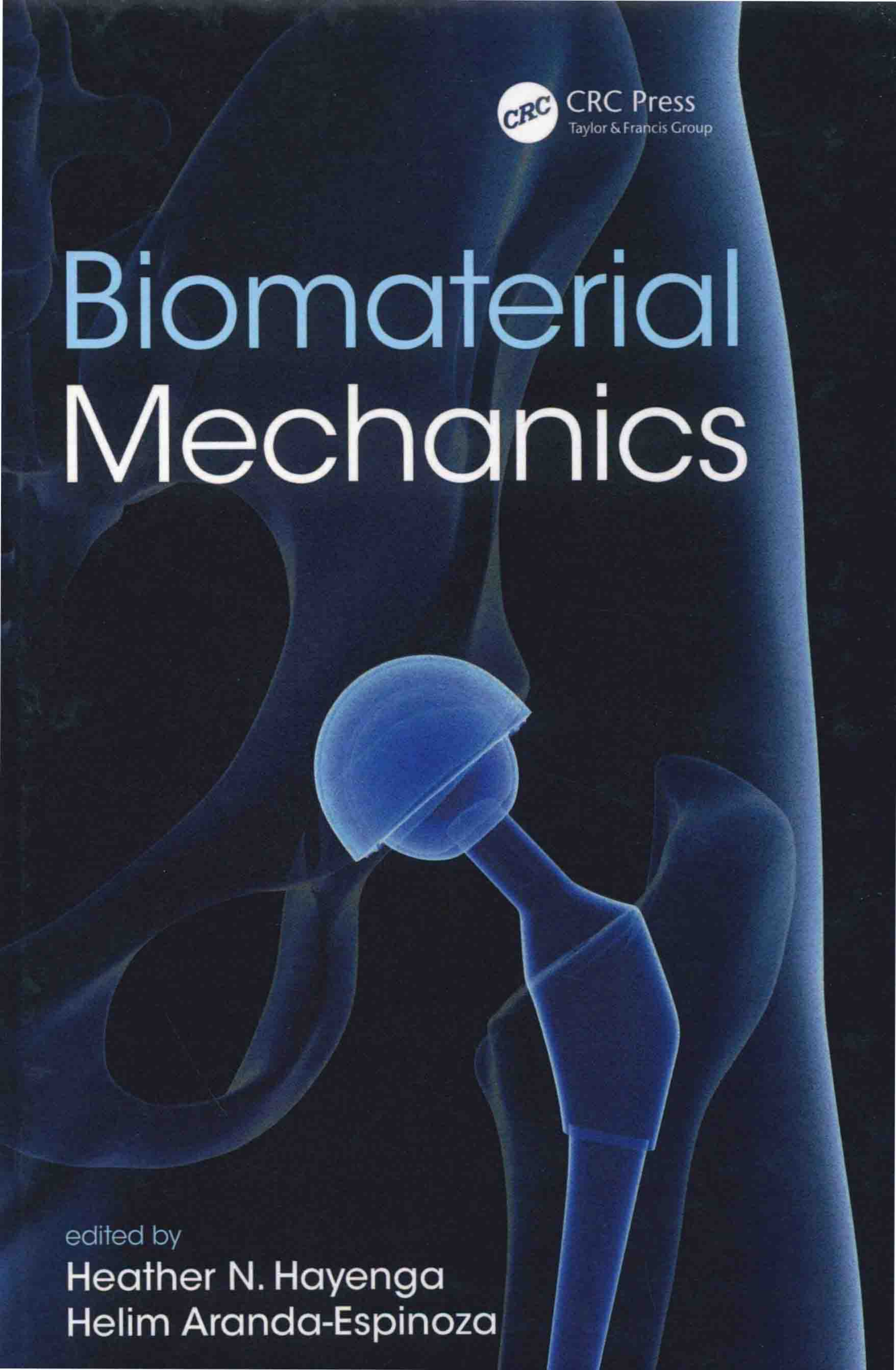

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Biomaterial Mechanics

edited by
Heather N. Hayenga
Helim Aranda-Espinoza

Biomedical Science

Biomaterial Mechanics

This book describes the fundamental knowledge of mechanics and its applications to biomaterials. An overview of computer modeling in biomaterials is offered and multiple fields where biomaterials are used are reviewed with particular emphasis on the importance of the mechanical properties of biomaterials. The reader will obtain a better understanding of the current technologies to synthesize and integrate biomaterials into the human body.

Special features

- Introduces the fundamentals of mechanics needed to work with biomaterials
- Presents an overview of current research in computer modeling for biomaterials
- Examines several fields of biomedical research
- Emphasizes current techniques to synthesize, characterize, and integrate biomaterials into the human body
- Offers a perspective chapter on the future of biomaterials mechanics

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CRC Press
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www.crcpress.com

6000 Broken Sound Parkway, NW
Suite 300, Boca Raton, FL 33487
711 Third Avenue
New York, NY 10017
2 Park Square, Milton Park
Abingdon, Oxon OX14 4RN, UK

ISBN: 978-1-4987-5268-8
90000
9 781498 752688

Hayenga
Aranda-Espinoza

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Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed on acid-free paper

International Standard Book Number-13: 978-1-4987-5268-8 (Hardback)

Library of Congress Cataloging-in-Publication Data

Names: Hayenga, Heather N., editor. | Aranda-Espinoza, Helim, editor.
Title: Biomaterial mechanics / [edited by] Heather N. Hayenga and Helim Aranda-Espinoza.
Description: Boca Raton : CRC Press/Taylor & Francis, 2017. | Includes bibliographical references and index.
Identifiers: LCCN 2017011216 | ISBN 9781498752688 (hardback : alk. paper)
Subjects: | MESH: Biocompatible Materials | Biomimetic Materials | Biomechanical Phenomena | Bioengineering--methods | Computer Simulation
Classification: LCC R857.M3 | NLM QT 37 | DDC 610.28--dc23
LC record available at https://lccn.loc.gov/2017011216

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Biomaterial Mechanics

Professor Heather N. Hayenga dedicates this book in loving memory to her generous and selfless father, Calvin Godfrey Hayenga, III.

Professor Helim Aranda-Espinoza dedicates this book to Joanna, Amaya, and Logan.

Preface

This book, *Biomaterial Mechanics*, comes in a timely manner as the biomedical field is realizing the importance mechanics plays in obtaining a successful healthcare outcome. Thus when asked by the publishers if we could coedit a book emphasizing the role of mechanics in biomaterials, we gladly accepted. This book provides an overview of the fundamental mechanical principles of biomaterials and the types of biomaterials used in healthcare. Moreover, an overview of elegant computational modeling approaches is presented with the applicable insights toward the refinement of biomaterial mechanics and biocompatibility.

In the wake of new technological advancements, biomedical materials have evolved in complexity and have played a crucial role in treating health ailments. The success of the biomaterial relies on multifaceted mechanical and biological interactions between the material and the host. Traditionally, materials were considered nearly homogeneous and assumptions to simplify material properties were appropriate, including assumptions that the materials only undergo small strains and the change in strain is linearly proportional to the change in stress. However, these assumptions are typically not appropriate when considering biological tissues that may undergo large strains, directional dependencies, or nonlinear stress–strain behavior. The first part of this book reviews mechanical principles of biomaterials, including how to appropriately test and calculate the mechanical properties of soft biological materials.

The next part of this book overviews the evolution of engineered biomaterials and implantable devices since 1950 when the field of biomaterials started to blossom. The increasing degree of sophistication has enabled biomaterials today to incorporate biological active components and dynamic behavior giving them crucial roles in injury repair, diagnostics, biological screening, drug delivery, and tissue engineering applications. There are many novel biomaterials on the horizon, including smart materials, shape memory polymers, 3D-printed biomaterials, and nanomaterials that have the potential to revolutionize healthcare in the future. This part specifically reviews properties of metallic, polymeric, nano, biological, and cancer-related biomaterials highlighting the key mechanical discoveries that will enable the eventual design, synthesis, characterization, and implantation of the optimal biomimetic material to treat a particular disease or substitute a tissue or entire organ.

In addition to the advanced manufacturing processes, computational modeling has allowed for a better understanding of how physical properties affect biological performance, as well as the interplay between various physio-mechano-chemical properties. The third part of this book highlights how computational biomechanical models can advance the field of device design. Modeling can enable time- and cost-efficient evaluations of fundamental hypotheses and thus reduce the experimental search space, and aid investigators in moving away from a purely empirical, trial-and-error approach toward rational design. In this part, the authors give concrete examples, including how computation modeling was used to determine optimal scaffold geometry, stiffness, degradation rates, and production rates of vascular grafts. Moreover, modeling can be used on a smaller scale to determine the molecular physicochemical interactions in biological systems and between biomaterials. More generally, a method called finite element analysis can be used to calculate stresses within biomaterials and tissues and thus proves a useful tool in evaluating the response of host tissue to an implanted biomaterial. In this part, the authors present the general principles of FEA and highlight how it is useful in evaluating the design and properties of cardiovascular stents. Overall, inclusive models that apply principles from engineering, material science, and biology will help develop and understand the mechanics of new materials better.

In summary, new processing techniques have enabled the fabrication of biomaterials that are more biomimetic than ever before. It can even be argued that some biomaterials have surpassed purely biomimetic materials. Moreover, advanced computational modeling has allowed for a better understanding of how physical properties affect biological performance, as well as the interplay between various physio-mechano-chemical properties. The ability to multiplex physical and chemical design parameters among single and multiple materials will help ensure compatibility and optimal performance of biomedical devices. It is an exciting time to explore the various parameters that control the physio-mechano-chemical properties of biomaterials. This book will help provide the background knowledge needed to pursue such endeavors.

The authors of this book are leading experts of their respective content. Each chapter is written independently of one another and can therefore be read individually and not necessarily in sequence. However, the logical progression of the book will provide interested readers with a comprehensive knowledge on how to test and characterize the mechanical properties of biomaterials, the types and mechanical properties of biomaterials used in the biomedical field, the advantage and insights obtained through computationally modeling the mechanical and biological interactions of biomaterials, and finally hypothesize as to where the field of novel biomaterials is headed in the future. Personally, as editors, we have learned a lot on each subject and expect the reader will also learn many new facets of the evolving field of biomaterials. Please enjoy your copy of *Biomaterial Mechanics*!

Heather N. Hayenga
University of Texas at Dallas
Richardson, Texas

Helim Aranda-Espinoza
University of Maryland
College Park, Maryland

Editors

Dr. Heather N. Hayenga is an assistant professor in the bioengineering department at the University of Texas at Dallas. She earned her BS in biomedical engineering on June 2005 from the University of California, Davis, and her PhD in biomedical engineering in 2011 from Texas A&M University. Dr. Hayenga then joined the University of Maryland as a postdoctoral fellow researching cellular biophysical phenomenon. To date, she has published 14 peer-reviewed manuscripts in the fields of biomechanics, mechanobiology, vascular biology, and immunology; has given more than 30 conference and invited talks; serves as a faculty advisor for the Biomedical Engineering Society (BMES) and the Society of Women Engineers (SWE); and serves as a reviewer for many grant and journal organizations. After joining UT Dallas in 2013, Dr. Hayenga developed and principals the Vascular Mechanobiology Laboratory. Her primary research interests include developing predictive growth and modeling tools of the vasculature, investigating the mechanobiology of arterial cells, improving drug delivery through the blood–brain barrier, and refining cardiovascular biomaterials during stenting.

Dr. Helim Aranda-Espinoza is an associate professor in the Fischell Department of Bioengineering at the University of Maryland, College Park. Aranda-Espinoza leads the Cell Biophysics Laboratory. To date, he has published 42 peer-reviewed manuscripts in the fields of soft matter, leukocyte biophysics, lipid dynamics, neuroengineering, and, recently, cancer metastasis. He has received prestigious awards such as the NSF Career Award and the Human Frontier Science Program Award. His primary research interests include understanding how the mechanical environment dictates cell functions. This is accomplished through the application of theoretical and experimental physics and engineering to describe cell mechanics and problems encountered in biological systems.

Contributors

Katrina Adlerz
Fischell Department of Bioengineering
University of Maryland
College Park, Maryland

Shant Aghyarian
Department of Bioengineering
University of Texas at Dallas
Richardson, Texas

Said Aranda
Instituto de Física
Universidad Autónoma de San Luis Potosí
San Luis Potosí, Mexico

Helim Aranda-Espinoza
Fischell Department of Bioengineering
University of Maryland
College Park, Maryland

Christopher K. Breuer
Tissue Engineering Program and Surgical Research
Nationwide Children's Hospital
Columbus, Ohio

Matthew Di Prima
Center for Devices and Radiological Health
U.S. Food and Drug Administration
Silver Spring, Maryland

John F. Eberth
Cell Biology and Anatomy Department and
Biomedical Engineering Program
University of South Carolina
Columbia, South Carolina

John P. Fisher
Fischell Department of Bioengineering
University of Maryland
College Park, Maryland

Sai J. Ganesan
Fischell Department of Bioengineering
University of Maryland
College Park, Maryland

Edna George
Department of Biosciences and Bioengineering
Indian Institute of Technology Bombay
Mumbai, India

Izabelle M. Gindri
Department of Bioengineering
University of Texas at Dallas
Richardson, Texas

Heather N. Hayenga
Department of Bioengineering
University of Texas at Dallas
Richardson, Texas

Kim L. Hayenga
Biomedical Engineer
San Mateo, California

Jay D. Humphrey
Department of Biomedical Engineering
Yale University
New Haven, Connecticut

Ramak Khosravi
Department of Biomedical Engineering
Yale University
New Haven, Connecticut

Silvina Matysiak
Fischell Department of Bioengineering
University of Maryland
College Park, Maryland

Clark A. Meyer
Department of Bioengineering
University of Texas at Dallas
Richardson, Texas

Kristin S. Miller
Department of Biomedical Engineering
Tulane University
New Orleans, Louisiana

Jesse K. Placone
Department of Bioengineering
University of California, San Diego
San Diego, California

Mildred Quintana
Instituto de Física
Universidad Autónoma de San Luis Potosí
San Luis Potosí, Mexico

Radu Reit
Department of Bioengineering
University of Texas at Dallas
Richardson, Texas

Danieli C. Rodrigues
Department of Bioengineering
University of Texas at Dallas
Richardson, Texas

Lucas Rodriguez
Department of Bioengineering
University of Texas at Dallas
Richardson, Texas

Shamik Sen
Department of Biosciences and Bioengineering
Indian Institute of Technology Bombay
Mumbai, India

Tarek Shazly
Mechanical Engineering Department and
Biomedical Engineering Program
University of South Carolina
Columbia, South Carolina

Sathyanarayanan Sridhar
Department of Bioengineering
University of Texas at Dallas
Richardson, Texas

Walter E. Voit
Department of Mechanical Engineering and Materials Science and Engineering
University of Texas at Dallas
Richardson, Texas

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