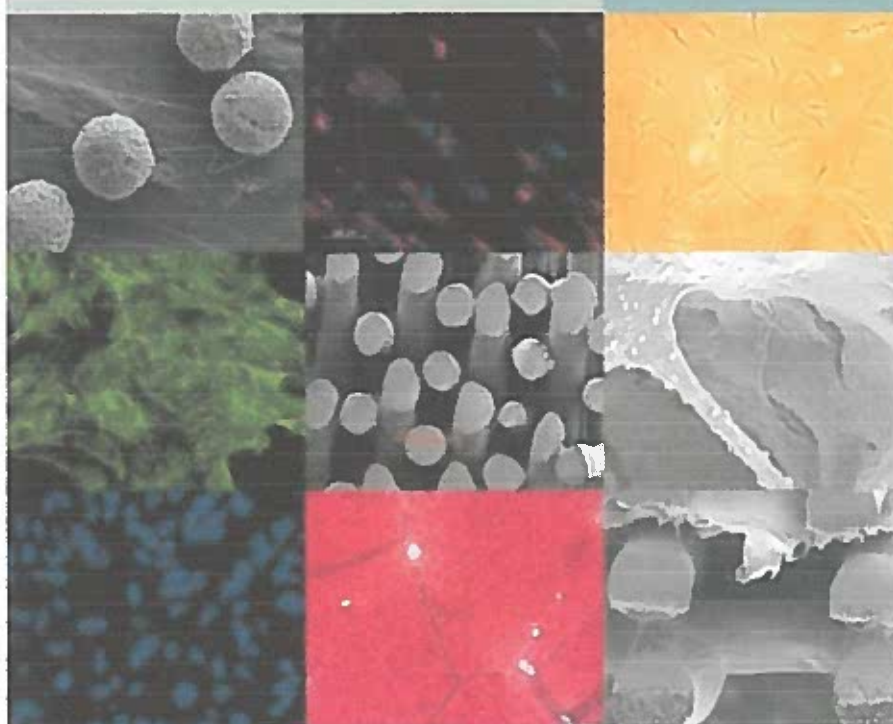


Copyrighted Material

BIOMATERIALS FROM NATURE FOR ADVANCED DEVICES AND THERAPIES

EDITED BY **NUNO M. NEVES AND RUI L. REIS**



Copyrighted Material

WILEY

BIOMATERIALS FROM NATURE FOR ADVANCED DEVICES AND THERAPIES

Edited by

NUNO M. NEVES

University of Minho

RUI L. REIS

University of Minho



WILEY

Copyright © 2016 by John Wiley & Sons, Inc. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4470, or on the web at www.copyright.com. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at <http://www.wiley.com/go/permission>.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services or for technical support, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit our web site at www.wiley.com.

Library of Congress Cataloging-in-Publication Data

Names: Neves, Nuno M., editor. | Reis, Rui L., editor.
Title: Biomaterials from nature for advanced devices and therapies / edited by Nuno Neves, Rui L Reis.
Description: Hoboken, New Jersey : John Wiley & Sons, Inc., [2016] | Includes index.
Identifiers: LCCN 2016017315 | ISBN 9781118478059 (cloth) | ISBN 9781119178071 (epub)
Subjects: LCSH: Biomedical materials—Therapeutic use.
Classification: LCC R857.M3 B5726 2016 | DDC 610.28/4—dc23
LC record available at <https://lccn.loc.gov/2016017315>

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

CONTENTS

CONTRIBUTORS **xix**

PREFACE **xxix**

PART I

1 Collagen-Based Porous Scaffolds for Tissue Engineering **3**

Guoping Chen and Naoki Kawazoe

- 1.1 Introduction, 3
- 1.2 Collagen Sponges, 4
- 1.3 Collagen Sponges with Micropatterned Pore Structures, 7
- 1.4 Collagen Sponges with Controlled Bulk Structures, 10
- 1.5 Hybrid Scaffolds, 12
- 1.6 Conclusions, 13
- References, 14

2 Marine Collagen Isolation and Processing Envisaging Biomedical Applications **16**

Joana Moreira-Silva, Gabriela S. Diogo, Ana L. P. Marques, Tiago H. Silva, and Rui L. Reis

- 2.1 Introduction, 16
- 2.2 Extraction of Collagen from Marine Sources, 18
 - 2.2.1 Extraction of Collagen from Fish, Jellyfish and Molluscs, 19
 - 2.2.2 Extraction of Collagen from Other Sources: Marine Sponges, 22

- 22.3 Some Selected Applications of Molecularly Imprinted Cryogels (MIC) for Macromolecules, 414
- 22.4 Concluding Remarks and Future Perspectives, 421
- References, 423

23 Immunogenic Reaction of Implanted Biomaterials from Nature 429

Martijn Van Griensven and Elizabeth Rosado Balmayor

- 23.1 Introduction, 429
- 23.2 Implantation Leads to Tissue Injury, 430
- 23.3 Inflammatory Responses, 431
 - 23.3.1 Acute Inflammation, 431
 - 23.3.2 Chronic Inflammation, 433
- 23.4 Foreign Body Reaction, 433
- 23.5 Immunogenic Reactions Towards Natural Biomaterials, 435
 - 23.5.1 Collagens, 435
 - 23.5.2 Fibrin, 435
 - 23.5.3 Hyaluronic Acid, 436
 - 23.5.4 Alginate, 436
 - 23.5.5 Chitosan, 436
 - 23.5.6 Fibroin, 437
 - 23.5.7 Combinations, 437
- 23.6 Final Remarks, 438
- References, 438

24 Chemical Modification of Biomaterials from Nature 444

J.C. Rodríguez Cabello, I. González De Torre, M. Santos, A.M. Testera, and M. Alonso

- 24.1 Protein Modification, 444
 - 24.1.1 Biological Incorporation of Non-Natural Amino Acids in Target Protein Using a Genetic Modification System, 445
 - 24.1.2 Labeling of Expressed Protein by Bioconjugation of Natural Amino Acids, 446
 - 24.1.3 Bio-Orthogonal Reactions of Proteins with Non-Natural Functional Groups, 448
 - 24.1.4 Enzymatic Site-Specific Modification, 449
 - 24.1.5 Ligand-Directed Labeling Chemistries, 449
- 24.2 Lipid Modifications, 451
 - 24.2.1 Acetylation, 452
 - 24.2.2 Epoxidation and Hydroxylation, 452
 - 24.2.3 Hydrogenation, 455
 - 24.2.4 Esterification, 456
- 24.3 Polysaccharide Chemical Modifications, 457
 - 24.3.1 Modifications Guided by Saccharide Oxygen Acting as Nucleophile, 457

24

CHEMICAL MODIFICATION OF BIOMATERIALS FROM NATURE

J.C. RODRÍGUEZ CABELLO, I. GONZÁLEZ DE TORRE, M. SANTOS, A.M. TESTERA, AND M. ALONSO

G.I.R. BIOFORGE (Group for Advanced Materials and Nanobiotechnology), Universidad de Valladolid – CIBER-BBN, Spain

24.1 PROTEIN MODIFICATION

Protein modification is an area of an intense research and many methods have been developed over the last 20 years (Carrico 2008,¹ Francis 2008,² Sletten and Bertozzi 2009),³ with applications in fields including biology, chemistry and medicine, as they are powerful tools for studying protein expression and localization, and engineering the functions of protein both *in vitro* and in live cells or *in vivo* to create new biocatalysts and bioanalytical tools. These enable improvement in bioavailability and pharmacokinetics of protein-based drugs and even the development of different biosensors. Nature uses covalent modification of proteins (phosphorylation, farnesylation, ubiquitination) to modulate their function and many natural products have adapted their structure for covalent binding to proteins (Drahl, et al. 2005,⁴ Pucheault 2008).⁵

It is clear that if we want to elucidate the functions of proteins and modulate their activities in a biological process, or if we want to introduce different molecules or synthetic probes onto protein structure to develop biomedical and biotechnological applications, it is necessary to develop high-precision protein modification methods in order to obtain well-characterized homogeneous products.

Thanks to site-specific modification of protein, structurally defined covalent linkages between proteins and surfaces, materials, or biomolecules may be created

- [137] Aoki N, Furuhashi K-I, Saegusa Y, Nakamura S, Sakamoto M. Reaction of 6-bromo-6-deoxycellulose with thiols in lithium bromide-N, N-dimethylacetamide. *Journal of Applied Polymer Science* 1996;61:1173–85.
- [138] Saad GR, Furuhashi K-i. Effect of Substituents on Dielectric β -Relaxation in Cellulose. *Polymer International* 1997;42:356–62.
- [139] Horton D, Hutson DH. Developments in the Chemistry of Thio Sugars. In: Melville LW, Tipson RS, editors. *Advances in Carbohydrate Chemistry*: Academic Press; 1963. p. 123–99.
- [140] Liu C, Baumann H. Exclusive and complete introduction of amino groups and their N-sulfo and N-carboxymethyl groups into the 6-position of cellulose without the use of protecting groups. *Carbohydrate Research* 2002;337:1297–307.
- [141] Cumpstey I. Chemical Modification of Polysaccharides. *ISRN Organic Chemistry* 2013;2013:27.
- [142] Knaus S, Mais U, Binder W. Synthesis, characterization and properties of methylaminocellulose. *Cellulose* 2003;10:139–50.
- [143] Liu C, Baumann H. New 6-butylamino-6-deoxycellulose and 6-deoxy-6-pyridiniumcellulose derivatives with highest regioselectivity and completeness of reaction. *Carbohydrate Research* 2005;340:2229–35.
- [144] Saad GR, Sakamoto M, Furuhashi K-i. Dielectric study of β -relaxation in some cellulosic substances. *Polymer International* 1996;41:293–9.
- [145] de Nooy AEJ, Besemer AC, van Bekkum H. Highly selective tempo mediated oxidation of primary alcohol groups in polysaccharides. *Recueil des Travaux Chimiques des Pays-Bas* 1994;113:165–6.
- [146] Parikka K, Leppänen A-S, Pitkänen L, Reunanen M, Willför S, Tenkanen M. Oxidation of Polysaccharides by Galactose Oxidase. *Journal of Agricultural and Food Chemistry* 2009;58:262–71.
- [147] Yang J-S, Xie Y-J, He W. Research progress on chemical modification of alginate: A review. *Carbohydrate Polymers* 2011;84:33–9.
- [148] Li Zhiyong, Ni Caihua, Xiong Cheng, Qian L. Preparation and Drug Release of Hydrophobically Modified Alginate. *Chemistry* 2009;2009:4.
- [149] Cathell MD, Szezewczyk JC, Schauer CL. Organic Modification of the Polysaccharide Alginate. *Mini-Reviews in Organic Chemistry* 2010;7:61–7.
- [150] Yalpani M, Hall LD. Some chemical and analytical aspects of polysaccharide modifications. III. Formation of branched-chain, soluble chitosan derivatives. *Macromolecules* 1984;17:272–81.
- [151] Rabea EI, Badawy MEI, Rogge TM, Stevens CV, Steurbaut W, Höfte M, et al. Enhancement of fungicidal and insecticidal activity by reductive alkylation of chitosan. *Pest Management Science* 2006;62:890–7.
- [152] Wijekoon A, Fountas-Davis N, Leipzig ND. Fluorinated methacrylamide chitosan hydrogel systems as adaptable oxygen carriers for wound healing. *Acta Biomaterialia* 2013;9:5653–64.
- [153] Chen S-C, Wu Y-C, Mi F-L, Lin Y-H, Yu L-C, Sung H-W. A novel pH-sensitive hydrogel composed of N,O-carboxymethyl chitosan and alginate cross-linked by genipin for protein drug delivery. *Journal of Controlled Release* 2004;96:285–300.