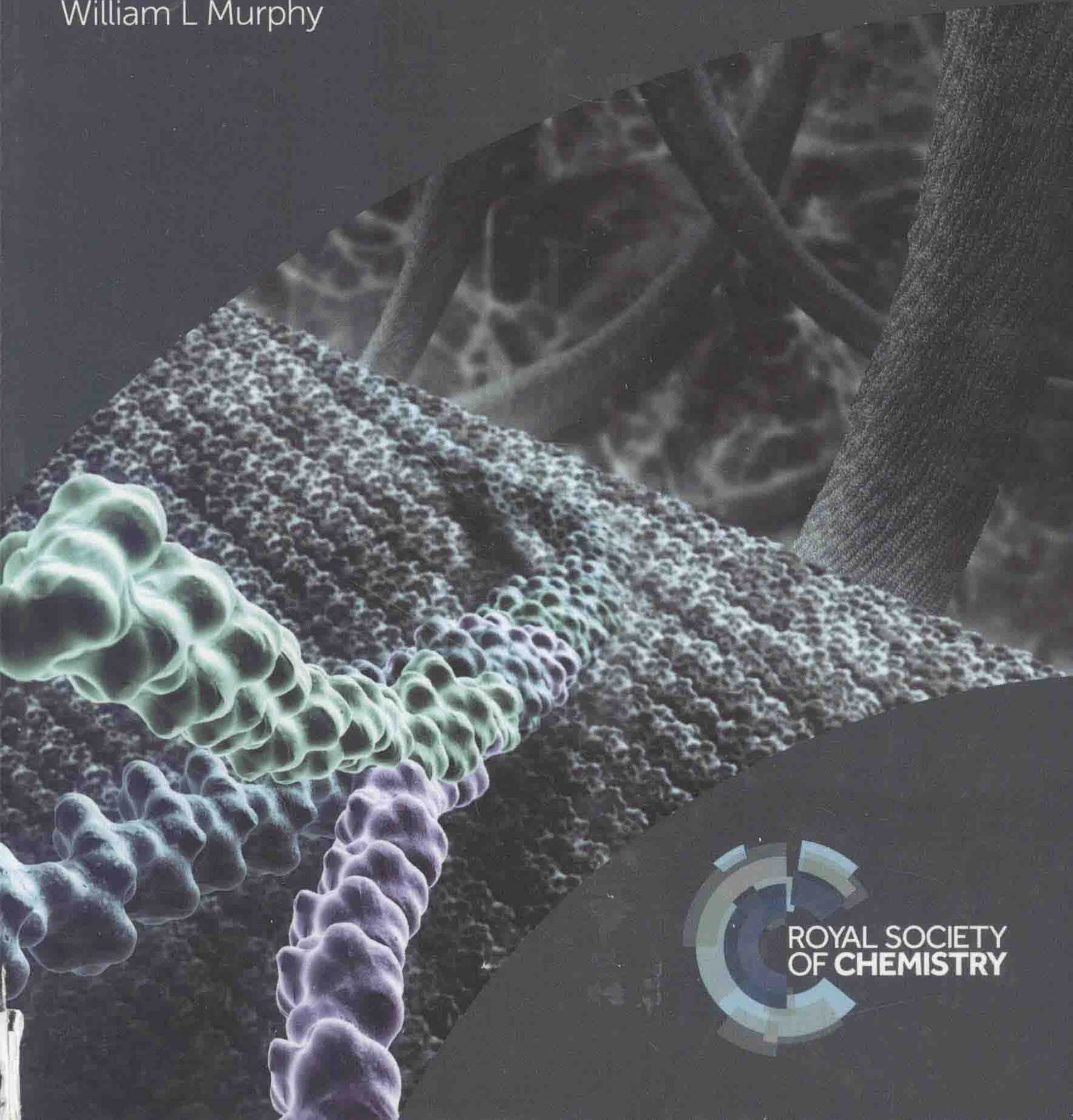
Mimicking the Extracellular Matrix

The Intersection of Matrix Biology and Biomaterials

Edited by Gregory A Hudalla and William L Murphy



ROYAL SOCIETY OF CHEMISTRY

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ROYAL SOCIETY OF CHEMISTRY

THE QUEEN'S AWARDS FOR ENTERPRISE: INTERNATIONAL TRADE 2013

Print ISBN: 978-1-84973-833-0

A catalogue record for this book is available from the British Library

Published by The Royal Society of Chemistry,
Thomas Graham House, Science Park, Milton Road,
Cambridge CB4 0WF, UK

Registered Charity Number 207890

Visit our website at www.rsc.org/books

Printed in the United Kingdom by CPI Group (UK) Ltd, Croydon, CR0 4YY, UK

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Preface

For at least 3000 years, humans have probed nature to identify new biomaterials, ranging from gut-derived sutures to metal tooth implants. Contemporary materials scientists continue to look to nature for innovative ideas, and this concept is now referred to as "biomimicry". Examples of biomimicry can be found throughout materials science, and virtually all implants used in modern medicine mimic some critical aspect of nature's materials. For example, polymer–ceramic composites have been designed based on the structure of bones and teeth, and elastomeric polymers have been synthesized to mimic the hierarchical ultrastructure and toughness of blood vessels and tendons. In each case, a detailed understanding of the fundamental composition and structure of natural materials has led to fundamentally new chemistries and fabrication techniques. In essence, the more we think of mother nature as a materials scientist—and the more we understand her design principles—the better we become at creating synthetic materials that are uniquely strong, tough, viscoelastic, dynamic, and/or biocompatible. Understanding the composition, structure, and function of nature's materials is the essence of "matrix biology", while designing and creating new materials using principles derived from biology is the essence of "biomaterials". *The guiding purpose of this book is to illuminate the exciting and dynamic intersection between matrix biology and biomaterials.*

While cells play a starring role orchestrating signaling dynamics during construction of human tissues and organs, the extracellular

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Published by the Royal Society of Chemistry, www.rsc.org

matrix (ECM) can be viewed as the quintessential material in human biology. The ECM can exhibit a diverse array of intricately controlled properties, including stiffness, elasticity, cell adhesivity, and binding affinity for biological signals. These properties are spatially patterned, and can dynamically vary over time, resulting in intriguing and important biochemical gradients. The rapid pace of discovery in matrix biology has been matched by the rate of innovation in biomaterials science. In particular, multi-scale characterization of the natural ECM has occurred in parallel with new developments in multi-scale design and fabrication of biomaterials. As a result, the intersection between matrix biology and biomaterials is an extraordinarily active, fruitful, and reciprocal scientific interface. The provenance of the macromolecules in the ECM and the way in which they are organized—from the nanometer scale to the macroscopic scale—serve as a rich feedstock of information for designing new biomaterials. It is clear that our deeper, fundamental understanding of each of the properties of the ECM results in direct applicability to biomaterials design.

A wide variety of innovative concepts has already come from the matrix biology/biomaterials interface (as detailed throughout the chapters in this book), and we anticipate that this book will have both intended and unintended outcomes for readers. One intended outcome of this book is to disseminate recent advances in synthetic biomaterials that are inspired by natural ECMs, and to inspire further innovations in biomimicry. Biomimicry has increasing relevance in health care, such as in regenerative medicine, and in development of enabling tools for life scientists. This text aims to unify the current knowledge of ECM biology with the state-of-the-art of ECM-mimicking biomaterials. In the process, the individual chapters provide instructions for development of new biomaterials that can have direct, near-term impact on health care and life science.

Our goals at the outset of this book project were to: (1) solicit chapters from the most knowledgeable and prominent matrix biologists; (2) solicit chapters from the most innovative biomaterials scientists; (3) arrange and connect the chapters in a way that provides comprehensive information; (4) ensure that each chapter illuminates the rich interface between matrix biology and biomaterials. To achieve these goals, chapters were authored by either a leading biologist or a leading bioengineer. "Matrix biology" chapters highlight a feature of native ECMs that is integral to tissue development and homeostasis. "Biomaterials" chapters then discuss the state-of-the-art of biomaterials that mimic ECM features. Ultimately, this book is intended to appeal to both biologists and bioengineers interested in the ECM, and provide a benchmark for future efforts to develop synthetic biomaterials as ECM mimics.

The editors would like to sincerely thank each of the contributors who have made this book possible. Authors were hand-picked for each individual topic area, based on their worldwide leadership in these areas and their deep appreciation for cross-disciplinary innovation. We have achieved our goal of illuminating the rich matrix biology/biomaterials intersection thanks to the brilliance and extensive efforts of the chapter authors. The resulting book comes at a critically important time in these rapidly emerging fields. We anticipate that it will provide information to those who are entering this new cross-disciplinary intersection, and serve as an inspiration for the next generation of highly innovative biomaterials scientists.

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Contents

Matrix Biology

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Biomaterials as Mimics of the ECM

A. Building Function Through Complexity