Nanotechnology and Tissue Engineering

The Scaffold

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Dedication

To my wife Cynthia, and my children,
Ti, Michaela, and Victoria

To my husband Prem and my son Bharath

Contents

SECTION III Promising Nanofabrication Techniques to Develop Scaffolds for Tissue Engineering

SECTION IV Applications of Nanostructured Scaffolds in Biology and Medicine

Foreword

I am delighted to write the foreword for *Nanotechnology and Tissue Engineering: The Scaffold* edited by Professor Laurencin and Dr. Nair. This book will be extremely useful as a reference source for all those working in the area of biomaterials, tissue engineering, and bio-nanotechnology. Today, science and technology at the nanoscale is capable of providing unprecedented understanding, control, and manipulation of matter at the atomic and molecular level. Nanotechnology has already had a significant impact on modern medicine through the development of novel targeted therapies, diagnostic and imaging techniques, as well as by providing novel strategies to repair and regenerate tissues. Nanofabrication techniques have opened the door toward developing unique structures, which would be of great value in regenerative medicine, by giving us the ability to mimic biological structures with molecular level precision, and thereby controlling or modulating cellular functions. The present work is timely and provides a fine summary of the present status of bio-nanotechnology aimed toward developing biomimetic scaffolds for tissue regeneration. The attraction of the book lies in the judicious combination of concise and comprehensive chapters covering the fundamentals of ideal scaffolds for tissue engineering, cellular behavior toward nanostructures, and state-of-the-art nanofabrication techniques for developing biomimetic nanostructures for tissue engineering. The collection of 14 chapters written by experts in their fields from different parts of the world presents an excellent overview of the subject for a wide audience. In my opinion, the book will provide a valuable resource to the field of bio-nanotechnology and tissue engineering.

C.N.R. Rao
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Distinguished Visiting Professor, Department of Materials, University of California, Santa Barbara

Preface

The aim of *Nanotechnology and Tissue Engineering: The Scaffold* is to provide a state-of-the-art, comprehensive account of research in the rapidly emerging areas of tissue engineering and nanotechnology. The tremendous advances in bio-nanotechnology during the past decade have significantly impacted the area of tissue engineering, opening up new avenues to realize the dream of regenerative medicine. This book is a natural presentation of the marriage of nanotechnology and tissue engineering, an emerging technology which has the potential to revolutionize medicine in the near future. The content of each chapter is written with a detailed background as the book covers a multidisciplinary area with audiences from various fields of professions ranging from engineers, clinicians, and scientists to graduate students and senior undergraduate students. The chapters also provide an extensive bibliography for the reader who wants to explore the subject to a greater depth.

The book is organized into 14 chapters, carrying the reader through the fundamentals of tissue engineering, comprehensive analysis of the unique cellular responses toward nanostructured materials, emerging nanofabrication techniques, and state-of-the-art reviews on the exciting breakthroughs using nanostructures in engineering three major tissues of the human body: neural, vascular, and musculoskeletal. Each of the 14 chapters is subindexed and titled so that the book can easily be used as a reference source.

We have chosen to present the materials under four sections: Section I clearly emphasizes the importance of scaffolds in tissue engineering. This section includes four chapters. Chapter 1 presents a broad overview of the area of tissue engineering and sets the stage for the rest of the book. Chapter 2 vividly presents the structure and functions of the extracellular matrix, the structure which tissue engineers are attempting to recreate using novel technologies. Chapter 3 discusses the functions and requirements of synthetic scaffolds for engineering tissues and Chapter 4 reviews the various microfabrication techniques currently being investigated for developing tissue engineering scaffolds. Section II is meant to emphasize the effect of nanostructures on cellular responses and tissue regeneration. Chapter 5 presents an in-depth discussion of the current literature on cellular responses toward nanostructured materials. Chapter 6 provides an overview of the various nanoscale biological surface modifications of biomaterials to improve cellular responses. Section III presents an overview of some of the most promising nanofabrication techniques to develop scaffolds for tissue engineering. Chapters 7 through 9 give a comprehensive account of the process of electrospinning and its versatility as a fabrication technique to form tissue engineering scaffolds. Chapter 10 discusses the various lithographic techniques toward developing nanostructured scaffolds for tissue engineering. Chapter 11 presents self-assembly as a unique fabrication method for developing biologically active scaffolds for accelerated tissue regeneration. Section IV provides an overview of some of the applications of nanostructured scaffolds in biology and medicine. Chapter 12 discusses the applications of nanostructured materials in neural tissue engineering, Chapter 13 in cardiovascular tissue engineering, and Chapter 14 in musculoskeletal tissue engineering.

It is our hope that all the chapters, written by eminent experts in the field, will provide a platform to better understand the impact of nanotechnology in the area of tissue engineering and regenerative medicine.

Cato T. Laurencin
Lakshmi S. Nair

Editors

Cato T. Laurencin is a professor of biomedical engineering and chemical engineering at the University of Virginia. He is also the Lillian T. Pratt distinguished professor and chairman of the Department of Orthopaedic Surgery at the University of Virginia, and orthopaedic surgeon-in-chief of the University of Virginia Health System.

Dr. Laurencin earned his BSE in chemical engineering from Princeton University, his MD from Harvard Medical School where he graduated magna cum laude, and his PhD in biochemical engineering/biotechnology from the Massachusetts Institute of Technology where he was a Hugh Hampton Young Scholar. Dr. Laurencin completed a residency in orthopaedic surgery at Harvard University where he was chief resident at the Beth Israel Hospital, Harvard Medical School. He also completed a clinical fellowship in shoulder surgery and sports medicine at the Hospital for Special Surgery, Cornell Medical College in New York. Clinically, Dr. Laurencin is board certified in orthopaedic surgery. He is a fellow of the American College of Surgeons, a fellow of the American Surgical Association, and a fellow of the American Academy of Orthopaedic Surgeons. For his clinical work, Dr. Laurencin was named one of the top 101 doctors in America by *Black Enterprise*, and has been named to America's Top Doctors and America's Top Surgeons.

Dr. Laurencin's academic interests are in the areas of tissue engineering, biomaterials, drug delivery, and nanotechnology. Dr. Laurencin was honored at the White House where he received the Presidential Faculty Fellowship Award from President William Jefferson Clinton in recognition of his research work bridging medicine and engineering. Dr. Laurencin is an international fellow in biomaterials science and engineering. He is the recipient of the William Grimes award from the American Institute of Chemical Engineers, the Nicolas Andry Award from the Association of Bone and Joint Surgeons for Orthopaedic Research, the Clemson Award from the Society for Biomaterials for contributions to the biomaterials literature, and the Leadership in Technology Award from the New Millennium Foundation.

Dr. Laurencin serves on the editorial board of 12 journals including *the Journal of Biomedical Materials Research*, *Biomaterials*, and *the Journal of Biomedical Nanotechnology*. He is also an assistant editor for *Clinical Orthopaedics and Related Research*.

In public policy, Dr. Laurencin is a member of the National Science Foundation's Directorate of Engineering Advisory Committee (ADCOM), and was a member of the National Science Advisory Board of the U.S. Food and Drug Administration (FDA). He recently also served in the leadership of the National Medical Association as speaker of the house of delegates and was a member of the NIH National Advisory Council for Musculoskeletal and Skin Diseases (NIAMS).

Dr. Laurencin is an elected member of the Institute of Medicine of the National Academy of Sciences.

Lakshmi Nair is an assistant professor at the Department of Orthopedic Surgery, University of Virginia. She received her MSc in analytical chemistry and MPhil in chemistry from the University of Kerala, India. Dr. Nair received her PhD in polymer chemistry on surface modification of polymers from Sree Chitra Tirunal Institute for Medical Sciences and Technology, India. She did postdoctoral training in the areas of biomaterials and tissue engineering at Drexel University and University of Virginia before joining the current position. Her research interests include hydrogels, nanomaterials, and tissue engineering. She has more than 60 publications in the area of biomaterials, hydrogels, drug delivery, and tissue engineering.

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