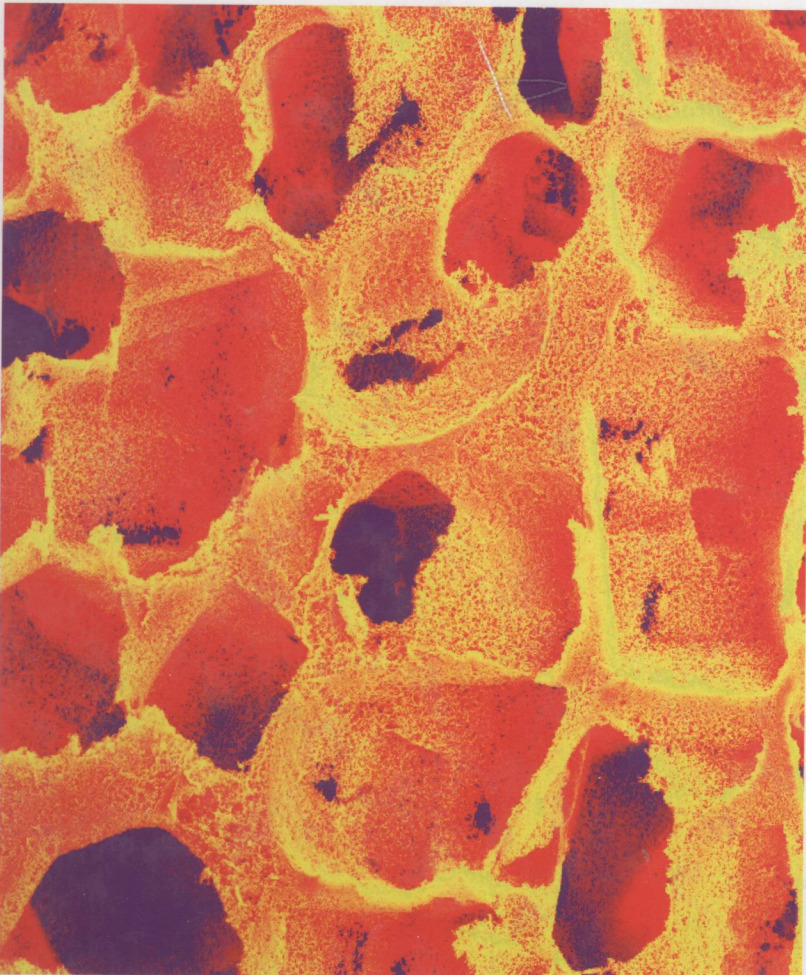


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Volume 9

Tissue, Cell and Organ Engineering

Edited by
Challa S. S. R. Kumar



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Challa S. S. R. Kumar*

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Preface

Tissue Cell and Organ Engineering is the title of the ninth volume of the series on Nanotechnologies for the Life Sciences. As the title indicates the book can be considered as an encyclopedia on nanotechnological approaches to tissue, cell and organ engineering. The publication of the book is timely for a number of reasons. First, with the increase in life expectancy there is an unfulfilled demand for replacing non functional tissues and organs. Second, life time for implants and vascular grafts made from conventional synthetic materials (with constituent dimensions greater than 1 micron) is limited ranging from 5 to 15 years. Third, utilization of living tissue/organ for replacement is not a practical solution as evidenced by the fact that millions of surgeries are performed annually to treat tissue and organ failure and the number of people waiting for such transplantations are more than 80,000 at any time. Fourth, there is the ever-increasing cost of health care related to tissue loss or end-stage organ failure exceeding 400 billion US dollars. Furthermore, laboratory experiments to date suggest that nanomaterials have great potential for tissue, cell and organ engineering. Until the publication of this book, there is no single source of information about how nanotechnologies are impacting various facets of tissue engineering. With close to five hundred pages, the book has turned out to be a comprehensive source of information covering different types of nanomaterials being investigated for tissue, cell and organ engineering in addition to innovative strategies for assembling functional and structural artificial tissues.

I am extremely pleased with the final product, which is a tribute to harmonious integration of tissue engineering and nanomaterials science. Such an integration is only possible due to the scholarly presentations from some thirty researchers around the world, spanning twelve chapters. My special thanks to all of them for making this project a reality. I am always grateful to my employer, family, friends and Wiley-VCH publishers, who are part and parcel of this long journey into the union of nanomaterials and life sciences. I am thankful to you, the reader, who has taken time to join this journey. I do hope you will enjoy reading the book and will find it useful in your future endeavors. Let me first give you a bird's eye view of the various facets of tissue engineering being touched by nanomaterials prior to your plunging into the more specific topics.

In comparison with nanomaterials such as nanoparticles and nanotubes, nanofibers are more suitable for use as scaffolds in tissue engineering as they are

morphologically similar to natural scaffolds and possess suitable properties such as high porosity, various pore-size distributions, and high surface-to-volume ratio. The majority of the investigations being carried out by tissue engineering researchers centers on utilization of nanofibers for development of artificial tissues. Therefore, the first four chapters in the book have been dedicated to provide an understanding of various aspects of nanofibers with respect to tissue engineering. The book begins with a chapter on *Nanotechnology and Tissue Engineering: The Scaffold Based Approach* providing an overview of the importance of nanotechnologies in developing scaffolds that closely mimic the structure and functions of the extra cellular matrix (ECM). Lakshmi S. Nair, Subhabrata Bhattacharyya and Cato T. Laurencin from the University of Virginia, USA, have demonstrated the importance of the scaffold approach for utilizing nanostructured materials in engineering ECM replacements. Of the various types of nanofibers currently under investigation for tissue engineering, polymeric nanofibers have been attracting a great deal of attention especially for applications in the area of ophthalmology, hepatic biology, nerve, skin, bone and cartilage regeneration, heart and vascular grafts, and stem cell research. Researchers Seow Hoon Saw, Karen Wang, Thomas Yong and Seeram Ramakrishna from the National University of Singapore have contributed the second chapter by bringing out an exhaustive review on *Polymeric Nanofibers for Tissue Engineering* covering different types of nanofibers, fabrication methodologies, degradation kinetics, biocompatibility and their applications in regeneration of several types of tissues. Focusing more specifically on electrospinning technology, researchers Wan-Ju Li, Rabie M. Shanti and Rocky S. Tuan from the National Institute of Arthritis, and Musculoskeletal and Skin Diseases in Bethesda, USA, demonstrate that this technology is a useful, economical, and easily set-up method for the fabrication of three-dimensional, highly porous and nanofibrous scaffolds which have been shown to support cellular activities and tissue formation. Their contribution in the third chapter, *Electrospinning Technology in Tissue Engineering*, is a thorough review on not only electrospinning technology per se but also on various chemical, physical and biological properties of nanofibers prepared using this technology. In the fourth chapter, electrospinning technology is compared with two other well known approaches, namely self-assembly and phase separation for fabrication of nano-fibrous scaffolds. Researchers from the University of Michigan in Ann Arbor, USA, systematically analyze the differences and unique characteristics of the three approaches for the development of scaffolds and their applications in tissue engineering. This chapter, *Nano-fibrous Scaffolds and their Biological Effects*, reviewed by Laura A. Smith, Jonathan A. Beck and Peter X. Ma provides some useful insights into achieving the dream of engineering three-dimensional tissue formations.

The fifth chapter in the book, *Nanophase Biomaterials for Tissue Engineering*, contributed by R. Murugan and S. Ramakrishna from the National University of Singapore is a source of information on nanoscale biomaterials in particular, ceramic and polymer-based materials that are being investigated for tissue engineering applications. In addition to the fabrication techniques for nanobiomaterials, the chapter also provides information related to their influence on cells and cell growth. In

the next chapter, the sixth, reader's attention is brought to nanotechnologies that are bringing solutions to long-standing problems with current orthopedic implants. The chapter, *Orthopedic Tissue Engineering using Nanomaterials*, written by Michiko Sato and Thomas J. Webster from Purdue University and Brown University respectively in West Lafayette, USA, discusses the effect of ceramic, metallic, polymeric, and composite nanomaterials on cellular functions particularly related to the bone. Norberto Roveri and Barbara Palazzo from the University of Bologna in Italy provide an up to date review on hydroxyapatite nanoparticles, which are being thoroughly investigated as materials for bone substitution. In the seventh chapter, entitled *Hydroxyapatite Nanocrystals as Bone Tissue Substitute*, they describe morphological, structural, chemical-physical, and surface characteristics of hydroxyapatite nanocrystals, followed by research investigations leading to understanding their high bioactivity and ability to induce bone regeneration and remodeling.

Moving away from nanofibers, ceramic nanomaterials and hydroxyapatite nanocrystals, the eighth chapter, *Magnetic Nanoparticles for Tissue Engineering*, authored by Akira Ito and Hiroyuki Honda from Kyushu University and Nagoya University respectively in Japan contains research investigations about application of the magnetic force-based tissue engineering technique (Mag-TE) to cell-seeding (termed "Mag-seeding") and its effectiveness in enhancing cell-seeding efficiency, leading to three-dimensional porous scaffolds for tissue engineering. In addition to magnetic nanomaterials, carbon nanotubes (CNTs) have been attracting the attention of life scientists. Due to their extraordinary physical, chemical, mechanical and electrical properties, in particular single-walled carbon nanotubes (SWNTs) are being touted as materials that have immense potential to interface directly with biological systems leading to innovative applications. In the ninth chapter, Peter S. McFetridge and Matthias U. Nollert from the University of Oklahoma in Norman, USA, delve deeply into the applications of SWNTs in the field of tissue engineering. The chapter, *Applications and Implications of Single-Walled Carbon Nanotubes in Tissue Engineering*, provides the history behind the electrical stimulation of cells and the reasoning behind the use of SWNTs as a conductive material to support or promote organ regeneration with specific examples of applications of SWNT in tissue engineering from the literature.

Cellular engineering is conceptually more fundamental to tissue engineering and nanotechnologies are helping in modulating cellular functions as well. In the tenth chapter, a more specific case of the effect of nanomaterials on cellular engineering related to free radical mediated oxidative stress is examined. The chapter, *Nanoparticles for Cell Engineering—A Radical Concept*, is a contribution from the laboratories of Beverly A. Rzigalinski at Virginia College of Osteopathic Medicine and Virginia Polytechnic & State University in Blacksburg, USA. The authors describe in detail potential application of three nanoparticle redox reagents viz rare earth oxide nanoparticles (particularly cerium), fullerenes and their derivatives and carbon nanotubes in preservation of cellular redox status and treatment of disease. Adding to the specific case of cellular engineering described in the tenth chapter, Jessica Winter from Ohio State University in Columbus, USA, presents in the eleventh chapter an exhaustive review on engineering of cells using nanotechnolo-

gies. The chapter aptly entitled *Nanoparticles and Nanowires for Cellular Engineering* is a one-stop source of information on applications of nanostructures to cellular engineering in general and for manipulating specific cellular components. The chapter deals with a gamut of issues on nanomaterial-based cellular engineering related to a wide spectrum of biomedical applications ranging from tissue engineering, intracellular tracking, biosensing and drug delivery. The final chapter of the book is an excellent review on *Nanoengineering of Biomaterial Surfaces* contributed by Ashwath Jayagopal and V. Prasad Shastri from Vanderbilt University in Nashville, USA. In this chapter, a variety of surface engineering techniques are presented for achieving micro- and nanoscale surface features, in addition to their applicability in the construction of hard and soft materials and three-dimensional geometries relevant to cellular and tissue engineering. This chapter brings to close the first comprehensive treatise on nanotechnological approaches for tissue, cell and organ engineering and I am very confident that the book will be a knowledge base for further advances that are bound to take place in the near future.

June 2006
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Contents

Preface XV

List of Authors XIX

- 1 Nanotechnology and Tissue Engineering: The Scaffold Based Approach** 1
Lakshmi S. Nair, Subhabrata Bhattacharyya, and Cato T. Laurencin
- 1.1 Overview 1
- 1.2 Introduction 1
- 1.3 The Importance of Scaffolds in Tissue Engineering 4
- 1.4 Structure and Functions of Natural Extracellular Matrix 12
- 1.5 Applications of Nanotechnology in Developing Scaffolds for Tissue Engineering 21
- 1.5.1 Polymeric Nanofiber Scaffolds 23
- 1.5.1.1 Top-down Approaches in Developing Scaffolds for Nano-based Tissue Engineering 24
- 1.5.1.2 Bottom-up Approaches in Developing Scaffolds for Nano-based Tissue Engineering 33
- 1.6 Cell Behavior Towards Nano-based Matrices 39
- 1.7 Applications of Nano-based Matrices as Scaffolds for Tissue Engineering 43
- 1.7.1 Stem Cell Adhesion and Differentiation 43
- 1.7.2 Neural Tissue Engineering 47
- 1.7.3 Cardiac and Blood Vessel Tissue Engineering 49
- 1.7.4 Bone, Ligament and Cartilage Tissue Engineering 54
- 1.8 Conclusions 55
- References 56
- 2 Polymeric Nanofibers in Tissue Engineering** 66
Seow Hoon Saw, Karen Wang, Thomas Yong, and Seeram Ramakrishna
- 2.1 Overview 66
- 2.2 Introduction 67
- 2.2.1 History of Tissue Engineering and Nanofibers 67
- 2.3 Classification of Nanofibers 69
- 2.3.1 Synthetic Polymers 69
- 2.3.2 Biopolymers 69

| | | |
|----------|-------------------------------------------------------------------------------------------------|------------|
| 2.3.3 | Copolymers | 70 |
| 2.3.4 | Composite Polymers | 70 |
| 2.4 | Nanofiber Fabrication | 70 |
| 2.4.1 | Drawing | 71 |
| 2.4.2 | Template Synthesis | 71 |
| 2.4.3 | Phase Separation | 72 |
| 2.4.4 | Self-assembly | 73 |
| 2.4.5 | Electrospinning | 73 |
| 2.5 | Degradation and Absorption Kinetics of Nanofiber Scaffolds Compared with Conventional Scaffolds | 74 |
| 2.6 | Advantages and Disadvantages of Nanofiber Scaffolds Compared with Other Conventional Scaffolds | 76 |
| 2.7 | Biocompatibility of Nano-structured Tissue Engineered Implants | 82 |
| 2.8 | Applications of Polymeric Nanofibers in Tissue Engineering | 87 |
| 2.8.1 | Ophthalmology | 89 |
| 2.8.2 | Liver | 93 |
| 2.8.3 | Nerve | 93 |
| 2.8.4 | Skin | 99 |
| 2.8.5 | Bone and Cartilage | 102 |
| 2.8.6 | Heart and Vascular Grafts | 105 |
| 2.8.7 | Stem Cells | 109 |
| 2.9 | Innovations in Nanofiber Scaffolds | 111 |
| 2.10 | Conclusion | 115 |
| | References | 116 |
| 3 | Electrospinning Technology for Nanofibrous Scaffolds in Tissue Engineering | 135 |
| | <i>Wan-Ju Li, Rabie M. Shanti, and Rocky S. Tuan</i> | |
| 3.1 | Introduction | 135 |
| 3.2 | Nanofibrous Scaffolds | 138 |
| 3.2.1 | Fabrication Methods for Nanofibrous Scaffolds | 138 |
| 3.2.1.1 | Phase Separation | 138 |
| 3.2.1.2 | Self-assembly | 138 |
| 3.2.1.3 | Electrospinning | 139 |
| 3.2.2 | The Electrospinning Process | 140 |
| 3.2.2.1 | History | 140 |
| 3.2.2.2 | Setup | 141 |
| 3.2.2.3 | Mechanism and Working Parameters | 142 |
| 3.2.3 | Properties of Electrospun Nanofibrous Scaffolds | 144 |
| 3.2.3.1 | Architecture | 144 |
| 3.2.3.2 | Porosity | 145 |
| 3.2.3.3 | Mechanical Properties | 146 |
| 3.3 | Current Development of Electrospun Nanofibrous Scaffolds in Tissue Engineering | 146 |
| 3.3.1 | Evidence Supporting the Use of Nanofibrous Scaffolds in Tissue Engineering | 146 |

| | | |
|----------|-----------------------------------------------------------------------------------------------------------|------------|
| 3.3.1.1 | Nanofibrous Scaffolds Enhance Adsorption of Cell Adhesion Molecules | 146 |
| 3.3.1.2 | Nanofibrous Scaffolds Induce Favorable Cell–ECM Interaction | 147 |
| 3.3.1.3 | Nanofibrous Scaffolds Maintain Cell Phenotype | 148 |
| 3.3.1.4 | Nanofibrous Scaffolds Support Differentiation of Stem Cells | 149 |
| 3.3.1.5 | Nanofibrous Scaffolds Promote <i>in vivo</i> -like 3D Matrix Adhesion and Activate Cell Signaling Pathway | 150 |
| 3.3.2 | Biomaterials Electrospun into Nanofibrous Scaffolds | 151 |
| 3.3.2.1 | Natural Polymeric Nanofibrous Scaffolds | 151 |
| 3.3.2.2 | Synthetic Polymeric Nanofibrous Scaffolds | 162 |
| 3.3.2.3 | Composite Polymeric Nanofibrous Scaffolds | 166 |
| 3.3.2.4 | Nanofibrous Scaffolds Coated with Bioactive Molecules | 168 |
| 3.3.3 | Engineered Tissues using Electrospun Nanofibrous Scaffolds | 169 |
| 3.3.3.1 | Skin | 169 |
| 3.3.3.2 | Blood Vessel | 170 |
| 3.3.3.3 | Cartilage | 171 |
| 3.3.3.4 | Bone | 172 |
| 3.3.3.5 | Muscle | 173 |
| 3.3.3.6 | Ligament | 175 |
| 3.3.3.7 | Nerve | 175 |
| 3.4 | Current Challenges and Future Directions | 176 |
| 3.5 | Conclusion | 177 |
| | References | 177 |
| 4 | Nanofibrous Scaffolds and their Biological Effects | 188 |
| | <i>Laura A. Smith, Jonathan A. Beck, and Peter X. Ma</i> | |
| 4.1 | Overview | 188 |
| 4.2 | Introduction | 188 |
| 4.3 | Methods of Formation | 190 |
| 4.3.1 | Electrospinning | 190 |
| 4.3.2 | Self-assembly | 193 |
| 4.3.3 | Phase Separation | 194 |
| 4.4 | Nanofibrous Composite Scaffolds | 198 |
| 4.4.1 | Inorganic Composites | 199 |
| 4.4.2 | Surface Modification | 200 |
| 4.4.3 | Factor Delivery Scaffolds | 201 |
| 4.5 | Biological Effects of Nanofibers | 202 |
| 4.5.1 | Attachment | 202 |
| 4.5.2 | Proliferation | 203 |
| 4.5.3 | Differentiation | 203 |
| 4.5.4 | Migration | 204 |
| 4.6 | Tissue Formation | 205 |
| 4.6.1 | Connective Tissue | 205 |
| 4.6.1.1 | Ligaments | 205 |
| 4.6.1.2 | Cartilage | 205 |
| 4.6.1.3 | Bone | 206 |

| | | |
|----------|-----------------------------------------------------------------------------------|------------|
| 4.6.2 | Neural Tissue | 207 |
| 4.6.3 | Cardiovascular Tissue | 208 |
| 4.6.3.1 | Cardiac Muscle | 208 |
| 4.6.3.2 | Blood Vessel | 208 |
| 4.6.4 | Liver Tissue | 208 |
| 4.7 | Conclusion | 209 |
| | References | 210 |
| 5 | Nanophase Biomaterials for Tissue Engineering | 216 |
| | <i>Ramalingam Murugan and Seeram Ramakrishna</i> | |
| 5.1 | Introduction: Problems with Current Therapies | 216 |
| 5.2 | Tissue Engineering: A Potential Solution | 219 |
| 5.3 | Stem Cells: The Essentials | 220 |
| 5.4 | Nanobiomaterials: A New Generation Scaffolding Material | 223 |
| 5.4.1 | Characteristics of Scaffold | 225 |
| 5.4.2 | Types of Scaffolding Materials | 227 |
| 5.4.2.1 | Ceramic Nanobiomaterials | 227 |
| 5.4.2.2 | Polymeric Nanobiomaterials | 234 |
| 5.5 | Nanofibrous Scaffold Processing: Current Scenarios | 237 |
| 5.5.1 | Self-assembly | 237 |
| 5.5.2 | Phase Separation | 239 |
| 5.5.3 | Electrospinning – A New Approach | 240 |
| 5.5.3.1 | Experimental System | 240 |
| 5.5.3.2 | Spinning Mechanism | 241 |
| 5.5.3.3 | Electrospun Nanofibrous Scaffolds | 243 |
| 5.6 | Cell–Matrix (Scaffold) Interactions | 244 |
| 5.6.1 | Cell–Ceramic Scaffold Interactions | 244 |
| 5.6.2 | Cell–Polymer Scaffold Interactions | 247 |
| 5.7 | Concluding Remarks | 248 |
| | Acknowledgments | 249 |
| | Abbreviations | 249 |
| | Glossary | 250 |
| | References | 252 |
| 6 | Orthopedic Tissue Engineering Using Nanomaterials | 257 |
| | <i>Michiko Sato and Thomas J. Webster</i> | |
| 6.1 | Preface | 257 |
| 6.2 | Introduction: Problems with Current Implants | 258 |
| 6.3 | A Potential Solution: Nanotechnology | 259 |
| 6.3.1 | Current Research Efforts to Improve Implant Performance Targeted at the Nanoscale | 260 |
| 6.3.1.1 | Ceramic Nanomaterials | 262 |
| 6.3.1.2 | Metal Nanomaterials | 270 |
| 6.3.1.3 | Polymeric Nanomaterials | 270 |
| 6.3.1.4 | Composite Nanomaterials | 274 |