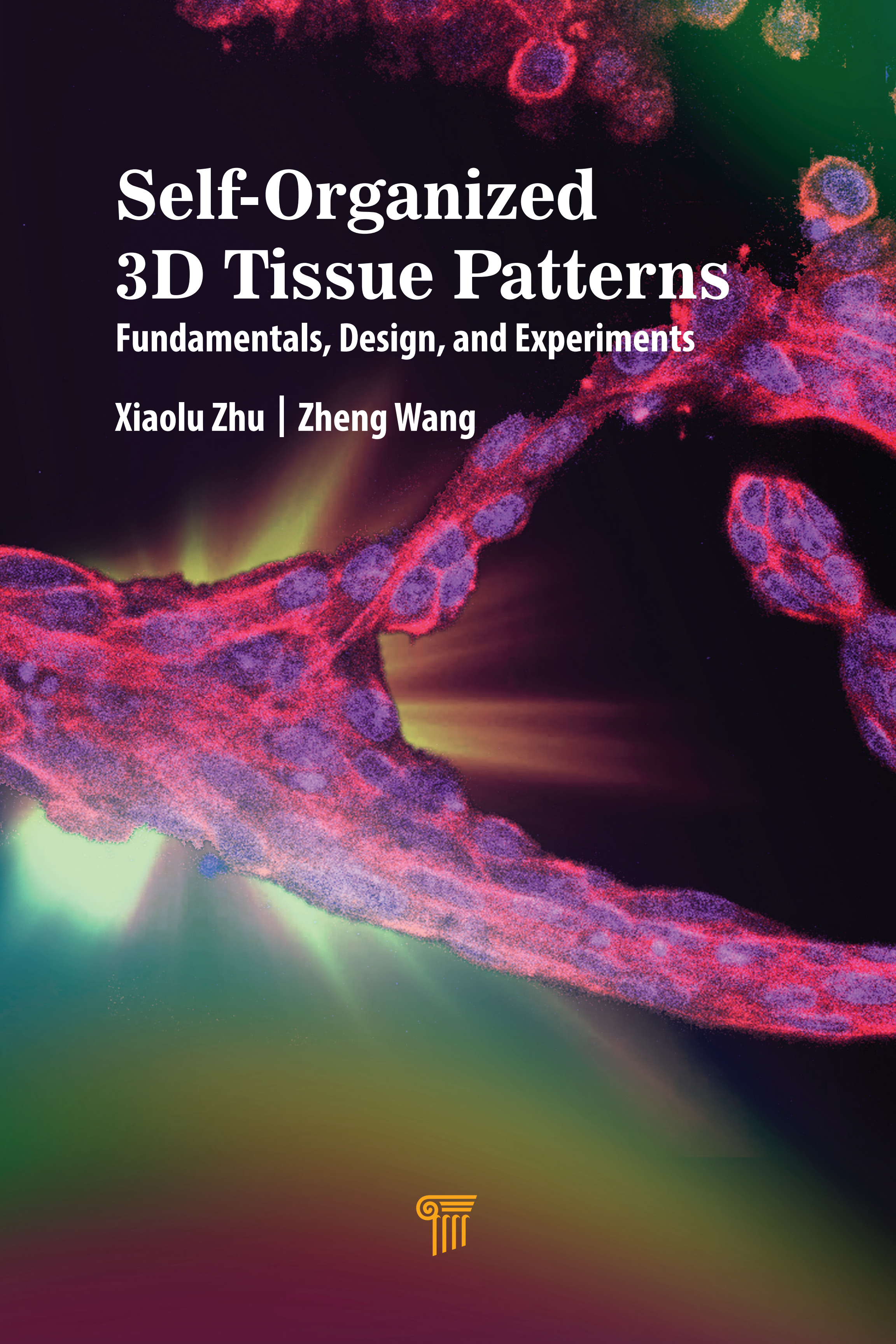
Self-Organized 3D Tissue Patterns

Fundamentals, Design, and Experiments

Xiaolu Zhu | Zheng Wang



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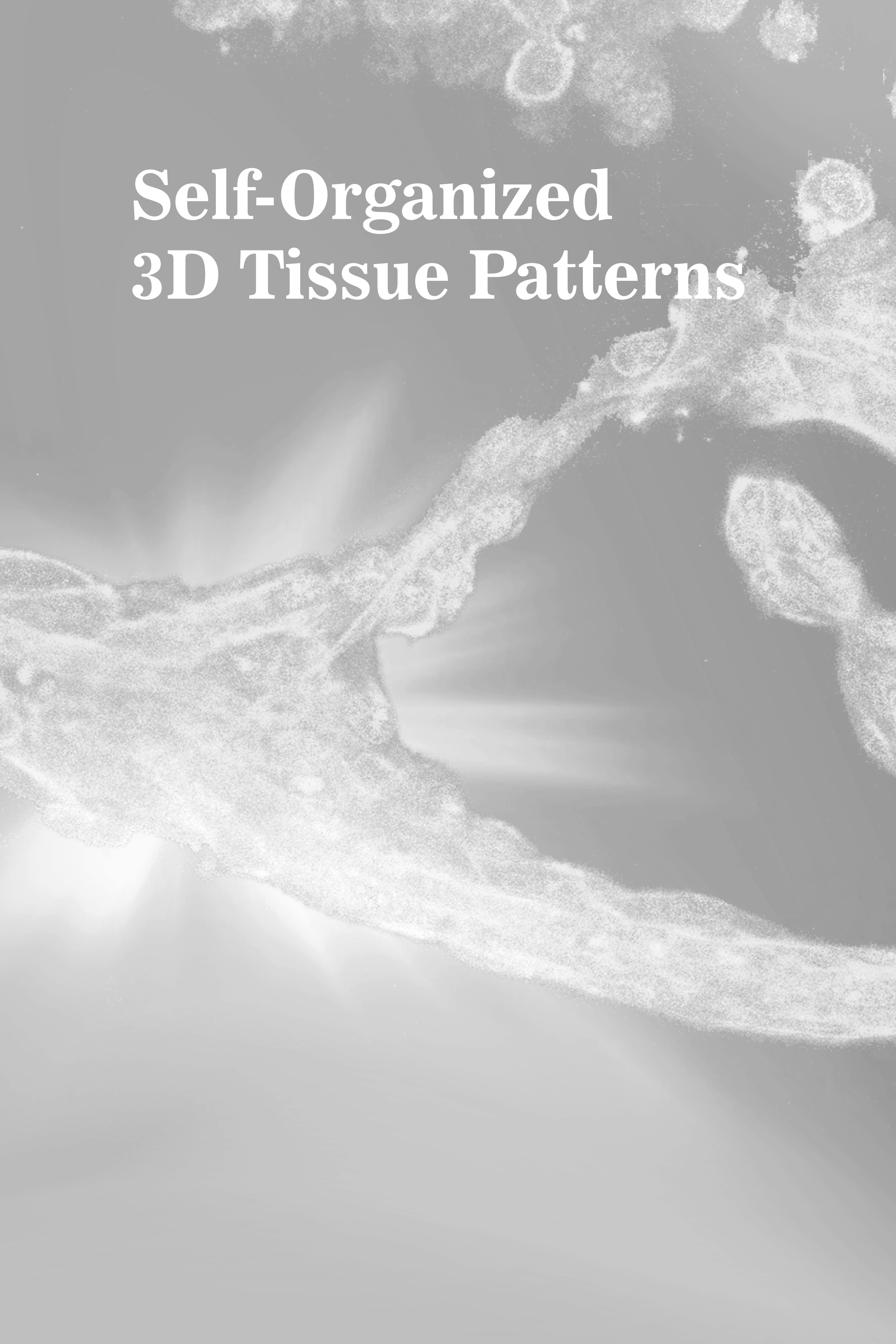

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Self-Organized 3D Tissue Patterns: Fundamentals, Design, and Experiments

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Preface

Tissue engineering applies principles and methods from engineering and life sciences to create artificial constructs to direct tissue regeneration or enhance tissues and organs. Structured scaffolds are widely useful for providing structures supporting cells to form 3D tissue. However, it is non-trivial to develop a scheme, which can robustly guide cells to self-organize into a tissue with desired 3D spatial structures. The self-organization of cells is a natural process that occurs in various biological bodies. In the field of engineering, we may expect that the process of self-organization can be rationally predicted and controlled. Moreover, it will be better that the self-organization of a huge number of cells can be governed by a mathematical framework.

This book first introduces the advances in tissue and organ regenerating using diverse technologies from different disciplines (Chapter 1). Then, it focuses on the multicellular or tissue structure formation via self-assembly of cells in 3D hydrogels (Chapter 2 and 3). Based on the hydrogel fabrication technique, the tailored inner interfaces inside hydrogels have been proposed to stimulate the tubular microtissue formation via a self-assembly scheme (Chapter 4), and the corresponding mathematical framework and the simulation model are also presented and discussed (Chapter 5). Furthermore, in order to develop a more elaborate and sophisticated regulating method for tuning the collective cellular behaviors, we also propose a hydrogel system with 3D distribution of clustered compositions, which can tune the multicellular elongations and aggregations (Chapter 6). This book offers the fundamentals and innovative designs for the 3D hydrogel system and discusses the representatively experimental results on the self-organized 3D Tissue patterns.

The authors are grateful for the helpful discussion with Prof. Ting-Hsuan Chen at City University of Hong Kong, Prof. Chih-Ming Ho at the University of California, Los Angeles (UCLA)， Prof. Tatiana Segura at Duke University and Prof. Alan Garfinkel and Prof. Yin Tintut at UCLA, while conducting the related projects. We hope this book will be useful for the readers in the interdisciplinary areas of engineering, biology, and life sciences.

Xiaolu Zhu
Zheng Wang
Hohai University, China

"This book offers multidisciplinary knowledge and diverse approaches for constructing 3D multicellular patterns. It also provides an easy access to the related multidisciplinary fundamentals, design strategies, and experimental procedures for professional researchers and students."

Prof. Xiuli Cong
Zhejiang Hospital, China

"I am thrilled to see the authors putting their enthusiasm and professionalism in the research of 3D self-organized tissues using both experimental and simulation techniques. More importantly, the research is finally organized in such a smooth and logical way as a book. I recommend this book as a useful reference to researchers in both academia and industry, even students who are passionate about tissue engineering."

Dr. Kesong Hu
Applied Materials, Inc., USA

"This book focuses on the fascinating self-organizing approaches that integrate multidisciplinary knowledge for constructing 3D cellular patterns. It provides interesting and rich information for the professional researchers in the related fields."

Prof. Xianting Ding
Shanghai Jiao Tong University, China

Therapies for regenerating damaged tissue and organs have been attracting much attention. In order to efficiently regenerate the functions of living tissue and organs, diverse attempts have been made to utilize scaffolds to "mold" artificial tissue structures. However, the structural complexity of the reconstituted tissue is limited by the mechanical precision of scaffolds, which still causes problems arising from degradation, immunogenic reactions, and so forth. It is also being realized that ultimately the best approach might be to rely on the innate self-organizing properties of cells and the regenerative capability of the organism itself.

This book investigates the 3D-pattern formation and evolution mechanism in multipotent cells embedded in 3D semi-synthetic hydrogels and the control methodology for self-organized patterns. The authors theoretically and experimentally demonstrate several types of topological 3D-pattern formation by cells in a 3D matrix in vitro, which can be modeled and predicted by mathematical models based on the reaction-diffusion dynamics of various chemical, physical, and mechanical cues. The study, focused on the 3D pattern formation of cells, provides (i) a unique perspective for understanding the self-organized 3D tissue structures based on Turing instability, (ii) the scheme for rationally controlling the cellular self-organization via exogenous factors or tailored inner interfaces inside hydrogels, and (iii) the elaborate and sophisticated regulating method for tuning collective cellular behaviors in 3D matrices.

Xiaolu Zhu is associate professor at Hohai University, China. He graduated from Southeast University, China, in 2007 and obtained a PhD in 2014. He worked as a research scholar at the University of California, Los Angeles, from 2011 to 2013. His work is currently focused on understanding and controlling self-organized 3D patterns of cells and hydrogel-based biofabrication.

Zheng Wang is currently a master's student at the University of Hong Kong. He obtained his bachelor's degree from Hohai University in 2020. He is working on the development of the applications of hydrogels in the regulation of cellular behaviors and on the quantification of the relationships between cellular behaviors and the physical properties of the extracellular matrix.

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