Integrative Mechanobiology

The first of its kind, this comprehensive resource integrates cellular mechanobiology with micro-nano techniques to provide unrivalled in-depth coverage of the field, including state-of-the-art methods, recent advances, and biological discoveries.

Structured in two parts, the first offers detailed analysis of innovative micro-nano techniques including FRET imaging, electron cryomicroscopy, micropost arrays, nanotopography devices, laser ablation, and computational image analysis. The second part of the book provides valuable insights into the most recent technological advances and discoveries in areas such as stem cell, heart, bone, brain, tumor, and fibroblast mechanobiology.

Written by a team of leading experts and well-recognized researchers, this is an essential resource for students and researchers in biomedical engineering.

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Micro- and Nano- Techniques in Cell Mechanobiology

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Preface

Mechanical forces in cell microenvironments direct cellular and multicellular form and function. Cells sense the mechanical characteristics of their microenvironment and translate the mechanical cues to intracellular biochemical signals that regulate several cellular and molecular processes important in development, homeostasis, and disease. Much of our understanding of the molecular mechanisms underlying the ability of cells to sense and react to mechanical stimuli is largely based on traditional macroscale tissue culture assays. However, novel micro- and nanoscale techniques for investigating cellular mechanobiological processes in normal and pathophysiological contexts have been under intense development in recent years. These approaches are providing new insights into cell mechanotransduction and mechanobiological responses, leading to improved fundamental understanding of cell biology and new strategies for cell-based regenerative therapies. This book highlights many of those recent advances in integrative cellular mechanobiology, including new discoveries and micro- and nanoengineered technologies.

The two related themes in the book are "Micro-Nano Techniques in Cell Mechanobiology" and "Recent Progress in Cell Mechanobiology."

- Chapter 1 reviews micropatterning technologies for controlling input signals in cellular mechanosensing and FRET live-cell imaging for visualizing molecular networks.
- Chapter 2 discusses electron microscopy and three-dimensional single-particle analysis for discerning the molecular underpinnings of cellular processes.
- Chapter 3 describes stretchable micropost array cytometry for quantitative control and real-time measurement of both mechanical stimuli and cellular biomechanical responses with a high spatiotemporal subcellular resolution.
- Chapter 4 discusses micro-device arrays for applying dynamically controlled mechanical stimuli to cells cultured in 2-D and 3-D arrayed environments.
- Chapter 5 reviews micro-nano topographies mimicking native extracellular matrices for the regulation of cellular behaviors.
- Chapter 6 describes hydrolytically degradable hydrogels, protease-sensitive hydrogels with cell-controlled properties, and stimuli-responsive hydrogels with user-controlled properties.
- Chapter 7 reviews microengineered electrotaxis devices for directing cell migration.

- Chapter 8 reviews laser ablation in severing cellular structures and its application to the measurement of physical forces with minimal disruption of the cellular microenvironment.
- Chapter 9 discusses computational image analysis techniques that are used to analyze dynamic fluorescence microscopy images for cell mechanobiology applications.
- Chapter 10 highlights micro- and nanotools for investigating cell mechanics and mechanobiology with a focus on cancer cells.
- Chapter 11 reviews several types of stimuli-responsive polymeric materials that have been developed for directing cell fate.
- Chapter 12 discusses in vivo tissue level mechanical stimuli and in vitro stem cell mechanosensing.
- Chapter 13 discusses how mechanobiological stimulation aids in engineering vascular and valvular tissues, and the role for micro- and nanoscale technologies.
- Chapter 14 highlights micro- and nanoscaled in vitro testing platforms to better mimic the environment of bone cells and their applications to studying bone cell mechanobiology.
- Chapter 15 explains molecular mechanotransduction mechanisms involved in fibroblast mediation of wound healing and tissue fibrosis.
- Chapter 16 highlights recent studies using micropost array technologies to measure and manipulate the contractile response of stem cell derived cardiomyocytes.
- Chapter 17 reviews several micro-nano fabricated platforms applied to addressing T cell activation.
- Chapter 18 discusses microfluidics assays for investigating cellular morphogenesis in 3-D and tumor angiogenesis.
- Chapter 19 discusses recent progress and future directions regarding cellular mechanobiology as applied to neuronal function.

Many of the molecular mechanisms by which cells sense and respond to mechanobiological stimuli require further elucidation. It is likely that major advances to this end will come from powerful micro- and nanoengineered platforms and the creation of more physiologically relevant in vitro models of mechanotransduction. It is certain that we will witness more transformative techniques and intriguing new findings in cellular mechanobiology in the near future. We thank all of the chapter authors and reviewers, and hope this book contributes to the education of next-generation mechanobiologists and becomes a useful reference in the area of integrative cellular mechanobiology.

Yu Sun, Deok-Ho Kim, and Craig Simmons