Preface

During the past decade, molecular and cellular biophysics has emerged as one of the most active and exciting areas at the frontier of scientific research. It is a multi-disciplinary field that has many important applications in medicine, health care, life science and biology in general. In essence, the origins of many diseases and illness are rooted at the cellular level. Like molecular and cellular biology, molecular and cellular biophysics is also an indispensable part of the very foundation of contemporary medical and life sciences. In fact, cellular biophysics not only provides a theoretical foundation toward understanding biological processes such as the function of organs, tissues and their interactions, but also provides practical answers to medical treatment and pathology including molecular mechanism of diseases and infections. Because of rapid development of nano-science and nano-technologies, molecular and cellular biophysics not only offers a practical means but also the promise to treat and cure many diseases with which we as a human society are still struggling with. However, unlike molecular cellular biology, molecular and cellular biophysics, in particular molecular and cellular biomechanics, is still a field at its infancy. It is precisely because of this that makes cellular mechanics a promising and exciting research field to study and to work.

In this book, we have selected nine research works at the forefront of molecular and cellular biomechanics to be introduced to our readers. It is our opinion that these works represent the current trend and future directions of cellular biomechanics research. By compiling these different topics into one volume, a unique perspective is provided on the current state of cell mechanics research and what lies in the future.

Among these contributions, Romero and Arribas presented their groundbreaking work on three-dimensional cell model, cell growth dynamics algorithm, and associated large-scale finite element simulation through Chapter 1. In Chapter 2, Zeng, Li, and Kohles presented their work on multiscale simulations of soft contact and adhesion of stem cells. In this work, a soft matter model has been developed to model the mechanical mechanism of the mechanotransduction of stem cells. Focusing on molecular mechanics and genetic mechanism of cellular biology, Wu, Wang, and Cohen presented their molecular dynamics modeling of proteins in Chapter 3. More specifically, they employed a molecular dynamics and principal component analysis (MD-PCA) approach studying sickled hemoglobin-hemoglobin interaction, which is the main cause of sickle cell anemia. In Chapter 4, Qin, Chou, Kreplak, and Buehler presented their latest work on atomistic and coarse-grain modeling and simulations of cellular intermediate filaments. They not only presented their own work, but also provided a detailed tutorial on modeling and simulations of intermediate filament networks. Complementary to Qin et al's work, in Chapter 5, Hatami-Marbini and Mofrad give a tutorial overview of cytoskeletal mechanics and rheology, and the topics that they have touched on are from mechanics of intermediate filament, rheology of cytoskeleton network, experimental measurements and techniques, to computation and simulation approach. To capture the complexity of cell's constitutive behaviors, in Chapter 6, Vernerey presented a multiphase mixture cell model and its application to cell-substrate interactions. In the proposed multiphase cell model, it combines the continuum description of the stress fiber, mass transport, cytosol fluid motion, and G-actin monomer motion, etc. Not only does the multiphysics model couple and combine several different aspects of cell biology, but the author has also applied the latest extended finite element method (X-FEM) and level-set method to simulate cell contact and adhesion with an extracellular substrate. This has demonstrated how applied and computational mechanics can solve complex problems in cell mechanics. To investigate mechanotransduction of cells through a purely thermodynamic approach, Sarvestani presented his analytical cell adhesion model in Chapter 7 that takes into account the effects of substrate stiffness and how it affects the growth of nascent adhesion areas. In Chapter 8, Kohles provided a detailed account on the experimental biomechanics of a single cell, in which he has discussed a state-of-the-art opto-hydrodynamics technique for measuring isolated cellular mechanical properties. Finally, in Chapter 9, Shen discussed his nonlocal shell model to simulate the buckling of microtubules inside a cell. This is a good example that clearly shows how non-classical continuum mechanics can contribute to the understanding of cellular biology.

Finally, it is our hope that this volume will disseminate much useful information in cellular biomechanics to a larger community outside the area of applied mechanics, while arousing public interest in cell mechanics research and applications. Ultimately, we envision that these works would promote more in-depth study and research in cell mechanics and cellular biophysics.

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