Preface

The field of cell mechanics has seen extensive development over the past few decades. New technologies have been invented to finely manipulate the mechanical and geometrical characteristics of the cellular environment, to apply precise doses of mechanical load, and to image the induced cellular response at both subcellular and molecular levels. Mechanical stimulation has been shown to be as potent and significant as chemical stimuli in affecting virtually all aspects of cell function. This includes effects on individual cell processes such as adhesion, migration, division, and gene expression regulation, as well as on collective behaviors such as cell–cell interactions, matrix remodeling, morphogenesis, and disease. A comprehensive understanding of the complex mechanical interplay between cells and their surrounding extracellular matrix is a multiscale problem in time and space, ranging from the molecular level and millisecond time scale up to the multicell or tissue levels involving a time scale of days to months.

This book brings together experts in the field of cell mechanics to summarize cutting-edge research at the molecular, cellular, and tissue levels with a focus on cell–matrix interactions. At each length scale, key experimental observations and corresponding quantitative theoretical models are presented. The book is organized in three sections that correspond to those three hierarchical levels. In Section I, which is focused on the molecular level, the passive and active mechanical properties of cytoskeletal polymers and associated motor proteins are discussed along with the behavior of polymer networks in Chapters 1 and 3. The mechanical properties of the cell membrane are presented in Chapter 2, with an emphasis on membrane protein activation caused by membrane forces. The hierarchical organization of collagen fibrils is discussed in Chapter 4, revealing that a delicate balance exists between specific and nonspecific interactions to result in a structure with semicrystalline order as well as loose associations. Section II focuses on mechanics at the cellular level. In Chapter 5, the roles of matrix mechanical properties on cell adhesion and function are presented along with different mechanical mechanisms of cell–cell interactions. The effects of mechanical loading on cell cytoskeletal remodeling are presented in Chapter 6, summarizing various modeling approaches that explain possible mechanisms regulating the alignment of actin stress fibers in response to stretching. Mechanical testing of cell-populated collagen matrices is described in Chapter 7, along with theory relating the passive and active mechanical properties of the engineered tissues. Chapters 8 and 9 focus on cell migration behavior in 3-D matrices and in collective cell motility. Section III of the book concerns cellular mechanics at the tissue level. Starting with a summary of the pioneering studies of cell–matrix mechanics by Albert Harris, Chapter 10 is devoted to the role of mechanics in cartilage development. Chapters 11 and 12 describe the roles of both cellular and external forces on tissue morphogenesis. Finally, the roles of mechanical forces on tumor growth and cancer metastasis are presented in Chapters 13 and 14, respectively.

These chapters are not meant to provide a complete summary of current research in the field, but instead they provide a thorough description of the roles of mechanical forces in cell and tissue biology. Despite the range of concepts presented, the material in each chapter relates to that of the others. For example, tumor cell metastasis involves cell–cell interactions, cell migration in 3-D tissues, and collective cell migration. Similar connections can

be drawn between tissue morphogenesis and cell behavior in mechanically loaded tissues. All of these phenomena depend on the mechanical properties of active cytoskeletal polymer networks, cell membranes, and collagen fibrils. It is our hope that specific examples described herein, along with descriptions of associated theoretical models, will inspire future development of multiscale models that elucidate the roles of mechanical forces in cell–matrix biology.