Preface

Biomechanics of the urinary bladder as a subject for investigation is relatively young yet medical problems associated with it are as old as mankind. To unravel intricate mechanisms and thus develop effective treatments to bladder diseases requires a dynamic analysis of multifunctional integrative processes at all structural levels.

The predominant paradigm of the basic medical science is fundamentally reductionist. This way of thinking is described as “divide and conquer” and is rooted in the assumption that complex problems can be solved by splitting them into smaller, simpler, more tractable parts. Although this approach has been responsible for tremendous successes in the continuous revolution and evolution of molecular technologies and has created great expectations for application to improving diagnosing, treating, and preventing diseases, it is quite obvious that the merely reductionist methodology is a necessary, but not a sufficient, condition for gaining a comprehensive understanding of physiological mechanisms of interest. More specifically, it is critical to establish functional links between constructive elements and to study the biological system from the holistic perspective.

Considerable progress has been made during the last decade in our ability to model different parts of the human body. With improvements in computing technology it has become possible to simulate and study the functions of the heart, the stomach, the small and large intestines, the uterus, etc., with astonishing levels of anatomical and physiological realism, and to assess performance under normal and pathological conditions. However, the systematic analysis and modeling of the human urinary bladder is beginning to attract the attention of scientists.

The aim of this book is to provide an update on recent achievements in the field of biomechanics of the urinary bladder and to present a systematic development of a mathematical model of the organ as a thin soft biological shell. This book is not a textbook or workbook! We rather encourage a reader to treat it as a guidebook that opens the way to many unsolved problems (s)he can explore and addresses questions to think about. Therefore, this book could be useful to postgraduate students and researchers interested in the applications of computational mathematics and solid mechanics to modern problems of biomedical engineering and medicine.

A brief overview of the anatomy, physiology, and mechanics of the human urinary bladder with an emphasis on experimental facts required to justify assumptions and to formulate constructive hypotheses of models is presented in Chap. 1. The reader should not expect, though, to find a complete biomedical survey on the subject and is advised to consult special literature on the subject for further information.

The current trend in mathematical modeling of biomechanics of the bladder is reviewed in Chap. 2. The existing models treat the organ as a thin elastic membrane under the general assumptions of geometrical and physical nonlinearity. However, they are limited to analysis of the effects of different shapes of the bladder on stress–strain distribution during the filling stage and do not offer the desired insight into the physiological processes which explain its function.

The basic concepts of the theory of surfaces and thin soft shells essential to a subsequent understanding of the mathematical model of the bladder are discussed in Chaps. 3 and 4. The material is focused on correctness and depth of conceptual arguments without resorting to advanced mathematics so that the reader can easily comprehend the material.

The following Chap. 5 is dedicated to constitutive model for the biological tissue. It is considered as a chemically reactive mechanical continuum. The fundamental theoretical concepts and their ramifications are presented in ways that provide both their significance and biological validity.

A one-dimensional morphostructurally relevant model of the detrusor fasciculus is developed and studied numerically in Chap. 6. Attention is given to analyzing the generation and propagation of the electromechanical wave along the myofiber under normal physiological conditions and after application of different pharmacological compounds.

In Chap. 7 a theoretical framework for the analysis of integrated physiological phenomena in the urinary bladder is developed. The emphasis is given to modeling of intramural regulatory pathways, i.e., neuronal arrangements and their interconnections with the upper regulatory centers. The Hodgkin–Huxley formalism is adopted to describe the dynamics of electrical processes in neurons and synapses.

In the following Chaps. 7 and 8 processes of electrochemical coupling at cholinergic and adrenergic synapses and modeling the spectrum of possible responses produced by acetylcholine and adrenaline on the fasciculus are analyzed.

In Chap. 9 a mathematical formulation of the problem of competitive antagonists, allosteric interactions, and allosteric modulation of competitive agonists/antagonists, and numerically studied pharmacokinetics of drugs used in clinical practice to manage bladder dysfunction are presented.

A mathematical model of the human urinary bladder—an integrated mechanical and self-controlled neuroregulatory system—as a thin soft biological shell; the results of stress–strain distribution, electromechanical activity, and pharmacological modulation of the organ are presented in Chap. 10. It is important to note that the model contains numerous parameters and constants that have not yet been evaluated experimentally, e.g., mechanical properties of the human bladder under biaxial loading, constants of chemical reactions, and electrical properties of the detrusor. These parameters and constants were adjusted during numerical simulations to resemble the physiological and diseased states of the organ. Therefore, the results are not aimed to achieve an accurate quantitative representation but rather offer a descriptive qualitative evaluation of biomechanical processes in the bladder during filling and voiding.

The last chapter, Chap. 11 focuses on the latest achievements in the field of mathematical modeling in urology and outlines current challenges.

By presenting the underlying biological, chemical, and physical processes of bladder function within the unified context of mathematical models, we hope to have provided the reader with the knowledge and insights needed to solve medical problems related to organ dysfunction. We have done our best to make things straight.

This book has depended on the assistance, advice, and encouragement of many people. To all helpers we are deeply grateful. Our special thanks go to my colleagues Dr. D. Malcolm and Ms. C. Squires for their invaluable comments and suggestions on the improvement of the manuscript. Our gratitude extends to our families for their continuous support and finally, to the staff at Springer, Heidelberg, Germany which has published this book.

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