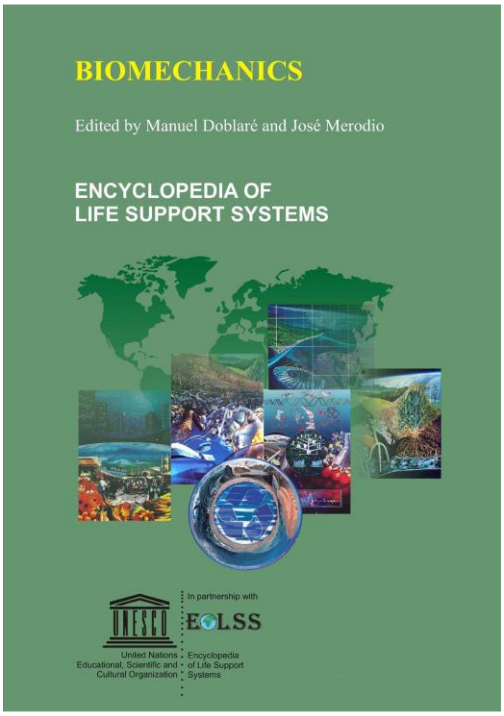
BIOMECHANICS



Biomechanics

No. of Pages: 498
ISBN: 978-1-78021-023-0 (eBook)
ISBN: 978-1-78021-523-5 (Print Volume)

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Preface

The enormous progress in the field of health sciences that has been achieved in the 19th and 20th centuries would have not been possible without the enabling interaction and support of sophisticated technologies that progressively gave rise to a new interdisciplinary field named alternatively as bioengineering or biomedical engineering. Although both terms are synonymous, the latter is less general since it limits the field of application to medicine and clinical practice, while the former covers semantically the whole field of interaction between life sciences and engineering, thus including also applications in biology, biochemistry or the many *-omics* subdisciplines. We use in this book the second meaning, recognizing the tremendous economic and social impact of the application of engineering into medicine that maintains the health industry as one with the fastest growth in the world economy.

Biomedical engineering not only applies engineering principles and methods to the design, manufacturing, testing, certification, marketing and repair of equipment, tools and medical technologies, but also is involved in the better understanding of fundamental scientific problems in health sciences by means of new imaging, sensoring and microscopy techniques, together with computational models or massive data analyses, among other methodologies. This is possible nowadays only with the concurrent interaction of all engineering disciplines, including electronics, informatics, materials science, mechanics, communications, chemistry etc., together with biological sciences, like genomics, proteomics, metabolomics, cell biology, physiology or medicine itself.

Biomechanics, in particular, aims to explain and predict the mechanics of the different components of living systems, from molecules to organisms as well as to design, manufacture and use of artificial devices that interact with the movement or resistance of living beings. It helps, therefore, to understand how living systems move, to characterize the interaction between forces and deformation along all spatial scales, to analyze the interaction between structural behavior and microstructure, to predict alterations in the mechanical function due to injuries, diseases or pathologies, to propose methods of artificial intervention for diagnosis or functional recovery, and, finally, to understand how living systems are able to adapt their internal structure, size and geometry to the particular mechanical environment in which they develop their activity.

In its broadest sense, biomechanics has been with us since the appearance of the first artifacts used by humans, when they used wooden sticks to fix bone fractures. In fact, movement of living bodies has amazed and intrigued humans always, as demonstrated in the many paintings in prehistoric caves showing birds flying or horses running. Many renowned scientists in history including Aristotle, Leonardo da Vinci, Galileo, Euler and Helmholtz, to name just a few, dedicated some of their studies to understand the fundamentals of the mechanics of life. Many authors suggest however that modern biomechanics did not truly emerge as a distinct field of study until the mid-1960s when the theoretical frameworks of nonlinear continuum mechanics and, in particular, of finite elasticity, viscoelasticity and mixture theory were established. The parallel development of the early generation of computers and numerical methods, as the finite element method, provided the enabling technology that allowed the exploitation of the whole potential of that theoretical framework. An important milestone was the publication of the book *Biomechanics: Material Properties of Living Tissues* in 1993 by Y.C. Fung, who is considered as the father of modern biomechanics. In recent years, however, biomechanics has taken off in importance, broadening its objectives and strongly increasing the number of scientists and companies involved. New technologies like sophisticated medical imaging, advanced modeling and simulation techniques, cell manipulation and less invasive *in vivo* testing procedures are revealing fundamental details of the main building blocks of life like genes, proteins, cells, tissues and organs and, in particular, the important interaction between mechanical strains and biological reaction, from microstructure evolution to development of pathologies and diseases such as scoliosis, malaria or cancer.

In addition to the traditional topics: analysis of movement of animals and humans, injury prevention, rehabilitation protocols and devices, prostheses, implants and ortheses design, mechanical devices like respiratory ventilators, rehabilitation machines or robotic surgery, vehicles with improved crashworthiness, sport performance, etc., new fields of application have appeared in the last years like cardiovascular performance, plastic surgery, tissue engineering, cell mechanics, biomimetic materials and artifacts, and many other. Biomechanics is today a highly interdisciplinary field that attracts the attention of engineers, mathematicians, physicists, chemists, material specialists, biologists, medical doctors, etc. They work in many different topics from basic Science to industrial applications and with an increasing arsenal of sophisticated modeling and experimental tools.

One purpose in this volume has been to present an overview of some of these many possible subjects in a self-contained way for a general audience. The book starts with an introduction, although with a more intensive focus on tissue biomechanics and mechanobiology, presenting some important aspects such as structure of biological tissues, tissue adaptation or tissue remodeling, fracture healing evolution and a recent but important application termed as tissue engineering. It concludes with a look at the future, discussing some of the most relevant challenges that may be foreseen in the field of tissue biomechanics. Chapters 1-3 are dedicated to the biomechanics of several important solid tissues, including the analysis of bone mechanical properties, microstructure and adaptation (Chapter 1), mechanical properties and long-term adaptation of, musculoskeletal soft tissues like ligaments, tendons and muscles (Chapter 2) and, finally, cardiovascular tissues, like blood vessels and heart (Chapter 3). Chapters 4-6 are dedicated to fluid mechanics in different systems like the circulatory system (Chapter 4), the respiratory system (Chapter 5) and the particular analysis of flow in collapsible tubes (Chapter 6). Then a new section dedicated to mechanobiology starts with two chapters, one studying the process of growth and remodeling (Chapter 7) and the other dedicated to cell mechanics (Chapter 8). The next three chapters deal with applications of biomechanics in orthopedics (Chapter 9), rehabilitation (Chapter 10) and human locomotion (Chapter 11). The last, Chapter 12, summarizes the state of the art of computer modeling in biomechanics ranging from molecules to whole systems, recognizing the real multiscale nature of these systems. We conclude this preface with some acknowledgements. First of all, we have to thank all the authors of the chapters since they have made this volume possible. All chapters have been peer-reviewed and our appreciation also goes to the reviewers for their helpful and constructive comments.

At last, we also have to thank the EOLSS-UNESCO staff for their technical support at every moment. We want to thank all of them for their patience and understanding during the preparation of this volume.

Manuel Doblaré, José Merodio
Editors of EOLSS Theme Biomechanics