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Book Review

Biomechanics: Mechanical Properties of Living Tissues, 2nd ed., by Y. C. Fung. Springer-Verlag, New York, 1993. 568 pages.

REVIEWED BY S. C. COWIN[1]

This book is the second edition of the first volume in a series of three volumes by Y. C. Fung on biomechanics. The first edition was published in 1981. The second volume in the series was *Biodynamics: Circulation* (1984) and the third was *Biomechanics: Motion, Flow, Stress, and Growth* (1990). In these three books Professor Fung describes the constitutive behavior of biological tissues, the functional mechanics of the body's organs and related engineering problems. The series of three volumes summarizes the application of an enormously wide spectrum of mechanics and thermodynamics to physiology and the engineering of biologically related problems. The mechanics applied includes rigid-body mechanics, mechanical vibration theory, viscous and perfect fluid theory, linear and nonlinear elasticity and viscoelasticity, wave propagation in fluid and solid media, multiphase mixture theory, chemical thermodynamics, and numerous subtopics of mechanics. The problems addressed cover the spectrum from birds flying and fish swimming to oxygen transport, human impact tolerance, cell behavior, and the engineering of activities at the cellular level.

The reviews of the first edition of this volume were "rave" reviews. In this journal (*Journal of Applied Mechanics*, 1982, Vol. 49, p. 464) Richard Skalak wrote that "Professor Fung is one of the few people who has kept up with the development of biomechanics on so many different fronts in the last decade and could single-handedly write this book for us." James McElhaney closed his review (*Medical Physics*, Vol. 9, 1982) with "For those of you interested in analysis of the mechanical properties of biologically derived tissues, this book is a must buy. Professor Fung has organized, consolidated, and unified this difficult field in an elegant and erudite textbook." In the dozen years between the first and second edition of this book Professor Fung has both widened and deepened his knowledge of the field of biomechanics and that enhanced vision is reflected in this new edition. The accolades appropriate for the first edition should be increased by 1/3 and applied to the second edition, for the second edition is 4/3 times the length of the first edition. This review is focused on the new 135 pages and the rewriting of the original 433 pages as the excellent and positive reviews of James McElhaney and Richard Skalak more than adequately covered the 1st edition.

Although Chapter 1 is rewritten and its length is increased by only four percent, the title of Chapter 1 is unchanged and remains "Introduction: A Sketch of the History and Scope of the Field"; similarly the titles of chapters 2 and 3, "The Meaning of Constitutive Equations" and "The Flow Properties of Blood", respectively, are unchanged although their content has been refined and their lengths are increased by ten percent. Chapter 4, formerly entitled "Red Blood Cells and Their Deformability" has become "Mechanics of Erythrocytes, Leukocytes and Other Cells" and now, 47 percent greater in size, includes not only the mechanics of the red blood cell (the erythrocyte), but also recent work on the basic cell mechanisms (e.g., adhesion) and other cells (e.g., leukocytes). Chapter 5, "The Rheology of Blood in Microvessels" has become "Interaction of Red Cells with Vessel Wall, and Wall Shear with Endothelium" and the chapter length has increased by 57 percent. Much of the new material concerns the endothelium and the transmission of the blood shear load to more solid structures in the body and models of the endothelial cell. Chapter 6 on "Bioviscoelastic Fluid" is unchanged in length while Chapter 7 on "Bioviscoelastic Solids," is 21 percent longer. Much of the new material on bioviscoelastic solids is concerned with the strain energy function in Professor Fung's finite deformation theory of the pseudo-elasticity for soft tissue behavior. Chapter 8 entitled "Mechanical Properties and Active Remodeling of Blood Vessels" is 73 percent longer than the same chapter in the previous edition where the chapter title did not contain the phrase "and Active Remodeling." Most of the increase in the chapter's length is associated with the material on active remodeling of the blood vessel, a technical area that Professor Fung has contributed to extensively in the last decade. Chapter 9 on "Skeletal Muscle" is 30 percent greater than in the first edition due to the inclusion of material on the cross-bridge hypothesis of the interaction of actin and myosin filaments. Chapter 10 on "Heart Muscle" has been extensively extended, reorganized and rewritten; it is now 50 percent longer than in the first edition. Chapter 11 on "Smooth Muscles" is 21 percent longer than in the first edition due to material on the active contraction of ureteral muscle and other smooth muscle organs. Chapter 12 on "Bone and Cartilage" is 32 percent longer with more information on the mechanical behavior of bone, articular cartilage, tendons, and ligaments.

The changes between the first and second edition of this volume reflect the exponential growth of significant research results in biomechanics during the past 12 years. The first edition was focused on the development of phenomenological constitutive equations for biological tissues and the only cell receiving significant attention was the red blood cell. In the second edition that focus is now joined with the development of microstructurally based constitutive equations and the broad application of mechanics to cellular level mechanisms.

I paraphrase the advice of James McElhaney in stating that for those of us interested in analysis of the mechanical properties of biologically derived tissues, this book is a must buy. In particular this update is significant and first editions should be replaced by the second edition.

[1]The City College, City University of New York, 107 West 86th Street, New York, NY 10024.

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