The Bioengineer's Bookshelf

Biomechanics: Mechanical Properties of Living Tissues. Y. C. Fung. 433 pp. $23.85. Springer-Verlag, New York, Heidelberg, Berlin, 1981.

Biomechanics has grown rapidly in the last decade and it is a pleasure to report that in this book an acknowledged leader in the field has set down a connected account of much of the progress that has been made in recent years. The book includes a good bit of anatomy, physiology, and analysis of systems, such as blood flow in tubes and muscle contraction which entails more than just physical properties in the usual sense. The balance of materials presented serves the purposes of the book very well. It will be especially appreciated by students of biomechanics. It can be expected that physiologists will also find it of interest. Established workers in other branches of theoretical and applied mechanics who wish to have an authoritative and collected introduction to biomechanics will also find the book valuable. It will be a welcome textbook in courses in biomechanics.

This book has a number of features that make it an especial pleasure to read through. First is the open style and the alternation of biological background and analytical representation which gives a degree of integration that has been often lacking in both the mechanical and biological literatures. Secondly there is a most interesting historical introduction in Chapter 1 which points out that biomechanics is a fairly old subject. Although biomechanics is a relatively new word, meaning the application of mechanics to biology, it turns out that the word mechanics is somewhat older than the word biology.

Thirdly, the exercises given in small print at the end of each chapter are unique in the biomechanical literature. In many cases they add to the content of the book by the ideas they suggest and the impetus to have the reader work out some of the details. Finally, as befits the subject, it may be seen from the reference lists in each chapter that a large fraction of the literature cited has been written in the last decade. 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.

There are some items in this book that probably deserve special mention as they are distinct contributions to the literature. One of these is the discussion of extreme values in relation to red blood cell sizes. Another is the consideration of the mechanics and thermodynamics of biological tissues in a single format. The discussion of inversion of stress-strain relations is an original and interesting contribution.

One of the virtues of a book like this is that the different parts of the subject can be treated with a uniform vocabulary and approach. The basic definitions of stress, strain, strain rate, and viscoelasticity are given in Chapter 2. While this information may not be new to graduate students in applied mechanics, it is useful to have it written down and connected to biomechanics in an orderly way. The Chapters 3, 4 and 5 deal with flow properties of blood, red blood cells and the deformability, and the rheology of blood in the microvessels. These chapters will give a fresh survey of the complicated field of blood cells properties and blood rheology. These chapters are a good example of Professor Fung's ability to set down the main facts in clear form. There is a good bit of advanced analysis in the literature which is not given here in any detail. Examples would be the solution of Stokes equations for various particles in capillary flow and the many different

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(*Cont'd from p. 231*)

models which have been studied for wave propagation in blood flow. Presumably these will be covered in two later volumes which Professor Fung has promised in the introduction to the present book.

Bio-viscoelastic fluids including protoplasm, mucous, saliva, cervical mucous, semen and synovial fluid are treated in Chapter 6. Here again the main facts and adequate references are well summarized.

The next five chapters deal with soft tissues and are largely drawn from the research work of Professor Fung, his associates and students. Chapter 7 on bio-viscoelastic solids is an especially long and important chapter. It contains informative descriptions of elastin and collagen. It also contains general discussion of thermodynamics of elastic deformation, generalized viscoelastic relations, the complementary energy function and inversion of stress-strain relationships. The idea of pseudoelasticity using a model of one elastic material in loading and another elastic material in unloading is developed. The reduced relaxation function is introduced and illustrated in this chapter by application to experimental data on rabbit mesentary. The notion of the reduced relaxation function is used repeatedly in the remainder of the book. It allows a reduction of a good deal of data on soft tissues which is highly nonlinear in its elastic behavior but linear in its viscoelastic response.

Chapter 8 deals with the mechanical properties of blood vessels. The arterial wall is another example in which the reduced relaxation function idea is useful. This chapter includes discussions of capillary blood vessels and the sheet flow in the aveolar walls of the lung which was developed by Professor Fung and his associates. The chapter closes with discussion of the properties of the veins but does not go into the many interesting phenomena that occur when veins collapse. These will no doubt appear in later volumes.

The next three chapters, Chapters 9, 10, and 11 on skeletal muscle, heart muscle, and smooth muscles are like a minibook within the book and surely represent a topic of great importance and particular interest. Here Professor Fung has tackled the different subject of describing the active contraction of muscles as well as their passive behavior when relaxed. Although some fault is found with Hill's classical three-element model, it is clear that the discussion is still an incomplete one. These chapters show that the variety and complexity of muscles is very great and a complete description must take into account a variety of detailed anatomical features and biochemical influences. The chapter on smooth muscle is most interesting, probably because the spontaneous cyclic contraction has an air of independence and mystery about it.

The book closes with Chapter 12 on bone and cartilage. This is a comparatively short chapter but gives the main known facts about the structure, variability and properties of bones. Although the strains are small because bones are stiff, the discussion of material properties is no less difficult than for soft tissues due to the complex heterogeneity and anisotropy of bones. The questions of growth and resorption in bone are dealt with only briefly but at least more rationally than much of the literature. The last few sections on cartilage

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(*Cont'd from p. 260*)
and lubrication of articular surfaces give the main effects leading to the very small coefficients of friction between typical articular cartilage surfaces. Synovial fluid is discussed back in Chapter 6.

There are omissions which one could complain about except that the subject is so large that something must be omitted. Workers interested in the cornea or other parts of the eye or the ear will probably feel left out. One area which has received no mention is that of the brain and neural system. This reviewer is convinced that neural mechanics is underdeveloped, say, compared to vascular mechanics and that the return on such development would be very much worthwhile. A discussion of teeth, the stiffness of their sockets, and the properties of the various components might also be of interest. Finally it should be pointed out that beside some data on frogs, almost all of the properties discussed are of mammalian tissues. Fish, plants, seashells, and other interesting forms such as coral are not mentioned. Of course the inclusion of all of these topics might require another volume, but people in agriculture and marine biology would probably like to see similar books for their fields

This is a book which will surely be a standard text for sometime. We will all be looking forward to seeing the two additional volumes which are promised in the introduction. The next volume will be on the mechanics of circulation and respiration. A third volume on advanced biomechanics will include recent developments where advanced methods in continuum mechanics and analysis have to be used. As Professor Fung has so aptly said in his preface, "Biomechanics at the level of current research cannot be bound by elementary mathematics." We will look forward to the forthcoming volumes to be as interesting and useful as the present first fine volume.

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Hard tissue, mineralized tissue, and calcied tissue are often used as synonyms for bone when describing the structure and properties of bone or tooth. The hard is self-evident in comparison with all other mammalian tissues, which often are referred to as soft tissues.Â Although bone is a viscoelastic material, at the quasi-static strain rates in mechanical testing and even at the ultrasonic frequencies used experimentally, it is a reasonable rst approximation to model cortical bone as an anisotropic, linear elastic solid with Hookeâ€™s law as the appropriate constitutive equation.