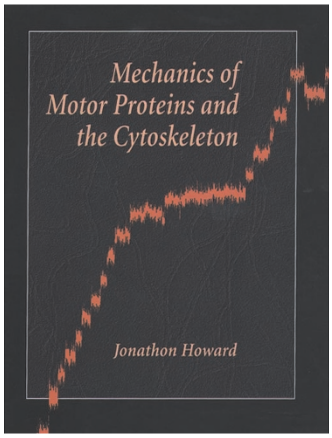
Physics of the cytoskeleton



Mechanics of Motor Proteins and the Cytoskeleton
by Jonathan Howard
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Spectacular progress has been made in our understanding of the physical processes that underlie the functions and mechanisms of cytoskeletal proteins. For example, the atomic structures of actin, tubulin and several motor proteins have been determined and quantitative models describing the mechanisms of force generation by filament polymerization/depolymerization and motor-protein action have been proposed. Moreover, advances in optical techniques have allowed biophysicists to observe and manipulate motor proteins and their dynamic tracks in a way that allows their activities to be measured directly as they operate at the nanometer, piconewton and millisecond scales. These amazing advances in cytoskeletal biophysics are the focus of the book, *Mechanics of Motor Proteins and the Cytoskeleton* by Jonathan (Joe) Howard, who is a leading expert in this field. Joe has clearly put an enormous amount of work into this project, and the result is an excellent text that is unique and original; by explaining how the mechanical properties of the cytoskeleton emerge from basic physical concepts, it fills a void and represents an extremely valuable addition to the cell-biology literature.

This text addresses fundamental questions about the nature of the forces that act to generate motion in the subcellular world. For example, what are the mechanical properties of individual proteins and protein polymers (are they hard, soft, stiff or flexible), how do actin and tubulin subunits polymerize into filaments, how do the ends of the filaments remain attached to an object in a way that allows coupling of subunit addition or dissociation to the exertion of pushing or pulling forces on that object, how do motor proteins generate force and move along a cytoskeletal track, what are the roles of thermal energy and energy derived from nucleotide hydrolysis in force generation and movement, and how do these forces contribute to cell structure, mechanics and motility?

To address these questions the book is organized into three sections that cover the physical principles governing the mechanical properties of protein molecules in part 1, the biophysical properties of cytoskeletal filaments in part 2 and the properties and mechanism of motor proteins in part 3. Similar to Howard Berg's classic text, *Random Walks in Biology* (Princeton University Press), part 1 clearly explains how 'life at low Reynold's number' — where viscous forces and thermal fluctuations are so dominant — differs from life at the macroscopic scale and there are many interesting surprises. For example, I had always thought of globular proteins as being like pliable rubber balls, instead of the hard plastic spheres that Joe describes. Most cell biologists will be acquainted with the material covered in parts 2 and 3 but the author delves deeper than usual into the physical principles that underlie the phenomena being described, and this in turn underlies the book's great strength. In each of the sections, general principles are emphasized, relevant equations that can be used to develop quantitative descriptions of cytoskeletal behaviour are included, and the main text is supplemented with illustrative and interesting cell-biological examples.

Mechanics of Motor Proteins and the Cytoskeleton is written for students of physics or biology who are interested in how the mechanical properties of protein molecules contribute to cell structure and motility. It is an advanced-level text, and the students who benefit from it will have already mastered basic cell biology, physics, biochemistry and calculus. The text could be used to supplement a graduate-level class on the biophysics of the cytoskeleton and it will be a valuable resource for the large number of graduate students, post-docs and other cell-biology researchers who study the cytoskeleton. Being a cell biologist who appreciates quantitative physical descriptions of cellular processes but who is not a card-carrying physicist, I found working through some of the material in the book heavy going but very worthwhile. The reward has been an improved understanding of the fascinating relationship between the fundamental physical properties of individual molecules and the mechanics and movements of cells.

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No rose comes without its thorns, however, and there are features of the book that, in my opinion, could be improved. For example, problem sets are appended to all the chapters in section 1, but not to most of those in the subsequent sections. This is unfortunate because the material presented on motor and cytoskeletal filaments is quite amenable to quantitative problem solving. In addition, solutions to the problem sets are not provided. Generally, I found that the material in the first section could have been better integrated with the other two sections. Some explanations in the text seem unnecessarily difficult — this is not helped by several typographical errors and some confusing use of motor nomenclature. Inevitably, what is included reflects Joe's own tastes and opinions, and readers should be prepared to supplement their reading with key papers that are not cited here.

But overall, this text is a very valuable contribution to the literature. It explains the basic physical principles governing the behaviour of cytoskeletal filaments and motors, it pulls together a large amount of conceptual and technical information, and in its current form it should occupy a place on the bookshelves of all cell biologists who study the cytoskeleton. I highly recommend it! □

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