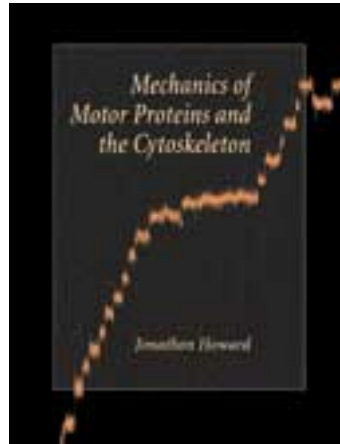




[list by author](#)
[list by title](#)
[list by subject area](#)



Mechanics of Motor Proteins and the Cytoskeleton

Jonathon Howard, Max Planck Institute for Molecular Cell Biology and Genetics

[About this Title](#)

[About the Author\(s\)](#)

[Reviews and Commentary](#)

[Table of Contents](#)

[Comment on This Title](#)

[Tell a Colleague About This Title](#)

Related subject areas:
[Cell Biology](#)

Publication Date: 2001
384 pages, 117 illustrations
ISBN: 0-87893-334-4
\$64.95
casebound

About This Title

Motor proteins are molecular machines that convert chemical energy from ATP hydrolysis into mechanical work, which powers cell motility. Over the last ten years, single-molecule techniques and structural studies have led to rapid progress in understanding how these biological motors operate. How do they move? How do they generate force? How much fuel do they consume, and with what efficiency? *Mechanics of Motor Proteins and the Cytoskeleton* brings these new findings together.

This book is for biology, physics, and engineering students who want to learn about the principles of protein mechanics and how it applies to the morphology and motility of cells. Understanding how motors and the cytoskeleton operate requires mechanical concepts such as force, elasticity,

damping, and work. Introductory physics textbooks address these concepts, yet they are concerned primarily with macroscopic systems, whose motions are qualitatively different from the highly damped, diffusive motion of individual molecules.

Mechanics of Motor Proteins and the Cytoskeleton provides a physical foundation for molecular mechanics. Part I explains how small particles like proteins respond to mechanical, thermal, and chemical forces, Part II focuses on cytoskeletal filaments, and Part III focuses on motor proteins. The treatments are unified in the respect that they are organized around principles rather than proteins: chapters are centered on topics such as structure, chemistry, and mechanics, and different filaments or motors are discussed together.

The book assumes a rudimentary knowledge of cell biology as well as freshman physics, though all concepts are introduced from first principles, and numerous boxed examples and figures aid the non-mathematical reader. For the mathematically inclined, detailed proofs of important results are included in the Appendix.

About the Author(s)

Jonathon Howard is currently a Professor of Physiology and Biophysics at the University of Washington in Seattle. In July, 2001, his research group will move to Dresden, Germany, where he is a Director of the Max Planck Institute for Molecular Cell Biology and Genetics. He earned a Ph.D. in Neurobiology at Australian National University, doing postdoctoral research there as well as at the University of Bristol and the University of California, San Francisco. Dr. Howard's current research interests include the mechanics of motor proteins and the cytoskeleton and mechanoelectrical transduction by sensory receptors. The recipient of several scholarships and fellowships, he most recently received a MERIT Award from the National Institutes of Arthritis and Musculoskeletal and Skin Diseases. The writing of *Mechanics*

of Motor Proteins and the Cytoskeleton was inspired by Dr. Howard's teaching of a course on Cell Motility at the University of Washington.

[Back to top](#)

Reviews and Commentary

"The cytoskeleton is an area of intense research and we are in danger of drowning in a sea of facts. What should we try to teach our students about it? . . . a textbook is needed which starts from first principles and leads to an understanding of the dynamics of the system. And here is that book."

—Edwin Taylor, *Nature*

"The book is a great launching point for gaining a biophysical understanding of the current detailed literature of motility which is increasingly filled with mathematical models describing motility data. As such, it will benefit students of a wide range of biological and physical backgrounds who are interested in understanding the nuts-and-bolts of cellular motility."

—Stephen J. King, *Cell*

[Back to top](#)

Table of Contents

Preface

1. Introduction

I. PHYSICAL PRINCIPLES

2. Mechanical Forces

- Introduction
- Force

- Motion of Springs, Dashpots, and Masses Induced by Applied Forces
- Motion of Combinations of Mechanical Elements
- Motion of a Mass and Spring with Damping
- Work, Energy, and Heat
- Summary: Generalizations to More Complex Mechanical Systems
- Problems

3. Mass, Stiffness, and Damping of Proteins

- Introduction
- Mass
- Elasticity
- The Molecular Basis of Elasticity
- Viscous Damping
- The Molecular Basis of Viscosity
- The Global Motions of Proteins are Overdamped
- The Motions of the Cytoskeleton and Cells are also Overdamped
- Summary
- Problems

4. Thermal Forces and Diffusion

- Introduction
- Boltzmann's Law
- Equipartition of Energy
- Diffusion as a Random Walk
- Einstein Relation
- Some Solutions to the Diffusion Equation
- Correlation Times
- Fourier Analysis
- The Magnitude of the Thermal Force
- Summary
- Problems

5. Chemical Forces

- Introduction

- Chemical Equilibria
- The Effect of Force on Chemical Equilibria
- Rate Theories of Chemical Reactions
- The Effect of Force on Chemical Rate Constants
- Bimolecular Reactions
- Cyclic Reactions and Free Energy Transduction
- Summary
- Problems

6. Polymer Mechanics

- Introduction
- Flexural Rigidity and the Beam Equation
- Applications of the Beam Equation: Bending and Buckling
- Drag Forces on Slender Rods
- Dynamics of Bending and Buckling
- Thermal Bending of Filaments
- Summary
- Problems

II. CYTOSKELETON

7. Structures of Cytoskeletal Filaments

- Introduction
- Structures of the Subunits
- Families of Cytoskeletal Proteins
- Filament Structures
- Summary: Structural Basis for the Length, Strength, Straightness, and Polarity of Filaments

8. Mechanics of the Cytoskeleton

- Introduction
- Rigidity of Filaments in Vivo
- Rigidity of Filaments in Vitro
- Summary: Material Properties of Cytoskeletal Proteins

9. Polymerization of Cytoskeletal Filaments

- Introduction
- Passive Polymerization: The Equilibrium Polymer
- Single-Stranded Filaments Are Short
- Multistranded Filaments Are Long
- Multistranded Filaments Grow and Shrink at Their Ends
- Other Properties of Multistranded Filaments
- Binding Energies and the Loss of Entropy
- Structure and Dimensionality
- Summary
- Problems

10: Force Generation by Cytoskeletal Filaments

- Introduction
- Generation of Force by Polymerization and Depolymerization in Vivo
- Generation of Force by Polymerization and Depolymerization in Vitro
- Equilibrium Force
- Equilibrium Force
- Brownian Ratchet Model
- Examples of Motility Driven by Actin Polymerization
- Other Kinetic Models
- Summary

11. Active Polymerization

- Introduction
- Actin and Tubulin Hydrolysis Cycles
- Filament Polarity, Treadmilling, and Nucleation
- Dynamic Instability
- Work during Polymerization and Depolymerization
- Structural Changes Attending Nucleotide Hydrolysis
- Summary

III. MOTOR PROTEINS

12. Structures of Motor Proteins

- Introduction
- Crossbridges and the Domain Organization of Motor Proteins
- Motor Families
- High-Resolution Structures
- Docking of Motors to their Filaments
- Summary

13. Speeds of Motors

- Introduction
- The Speeds of Motors in Vivo
- Rowers and Porters
- In Vitro Motility Assays
- Processive and Nonprocessive Motors
- The Hydrolysis Cycle and the Duty Ratio
- Analogies to Internal Combustion Engines and Animal Locomotion
- Summary: Adaptation to Function

14. ATP Hydrolysis

- Introduction
- ATP
- Coupling Chemical Changes to Conformational Changes
- Hydrolysis of ATP by Skeletal Muscle Myosin
- Hydrolysis of ATP by Conventional Kinesin
- Functional Differences between Kinesin and Myosin ATPase Cycles
- Summary

15. Steps and Forces

- Introduction
- Distances That Characterize a Motor Reaction
- Single-Motor Techniques
- Steps, Paths, and Forces
- The Structural Basis for the Duty Ratio
- Summary

16. Motility Models: From Crossbridges to Motion

- Introduction
- Macroscopic and Microscopic Descriptions of Motility
- Powerstroke Model
- Role of Thermal Fluctuations in the Power Stroke
- Crossbridge Model for Muscle Contraction
- Comparison of the Model to Muscle Data
- A Crossbridge Model for Kinesin
- Summary: Comparison between Motile Systems

Afterword

Appendix

Bibliography

Index

[Back to top](#)

Pricing and Options

Titles	ISBN	Price		
Mechanics of Motor Proteins and the Cytoskeleton	0-87893-334-4	\$64.95		

[home](#) || [contact us](#) || [list by author](#) || [list by subject area](#) || [list by title](#)

Other motor proteins include dyneins and kinesins, as well as non-muscle myosins. In addition to muscle contraction and amoeboid movement, these motors carry out such diverse tasks as the beating of cilia and the transport of vesicles within cells. To further compound the story, the cytoskeletal filaments are not just passive tracks; their polymerization drives a number of biological mechanisms, including the separation of chromosomes during mitosis, the intracellular movement of infectious agents, and protrusion of the acrosomal processes of some sperm.