PREFACE

INTRODUCTION

This book is an advanced-level introduction to the current state of knowledge in three active research areas: comparative biophysics, biomechanics, and bioengineering of animals. The general subject is animal locomotion including its evolutionary background and context. The three specific areas are swimming, natural flight, and terrestrial locomotion. This book is published in hardcover and as an online eBook. Both the volume itself and the chapters within it are organized so that they may be downloaded separately.

Chapters 1 and 2 provide contexts for the Chapters 3 through 5 within the frameworks of the scientific method and modern evolutionary biology. The specific discussions focus on the biophysical, biomechanical, and bioengineering bases for how macroscopic animals move around and survive in natural environments. Biomedical perspectives are secondary. The intended primary audience is advanced-level students and researchers mainly interested in and trained in mathematics, physical sciences, and engineering. Students with interests and backgrounds in many areas of biology (e.g., organismic biology, functional morphology, organ system and ecological physiology, physiological ecology, molecular biology, molecular genetics, and systems biology) should also find the volume useful, although some may find the mathematical approaches used occasionally challenging.

Modern biophysics, biomechanics, and bioengineering are actively growing, intellectually challenging, and highly visible interdisciplinary fields of research, development, and application. The largest parts of these fields study living (as opposed to fossil) animals, are biomedically oriented, and are increasingly centered on studies of what are called model organisms (e.g., in addition to the traditional laboratory rats, mice, and guinea pigs, roundworms [*Coenorhabditis*], fruit flies [*Drosophila*], and zebrafish [*Brachydanio*]).

Recently, these fields have undergone processes of internal differentiation, subdivision, and diversification that have broadly followed those existing in the more traditional areas of engineering. An analogy could be that relevant selected aspects of biology and biomedicine have been grafted onto major areas of engineering (e.g., mechanical, aeronautical, civil, marine, electrical, and chemical engineering). Regarding the physical sizes of the systems studied, there has been further differentiation into work on nano-, micro-, meso-, and macroscale systems.

The experience of the authors is that the basic training of many people primarily interested in mathematics, the physical sciences, and engineering often shows substantial gaps and imbalances with respect to some of the most relevant fundamentals of modern biology. This discrepancy is particularly the case for comparative organismic biology, biodiversity, phylogenetic systematic methods, paleobiology, and

organic evolution. It is also often true that their course work in biology emphasized molecular genetics and molecular, cellular, and tissue biology, whereas it de-emphasized or omitted organismic, evolutionary, organ system, comparative, ecological, environmental, behavioral, and population genetics and biology.

No single book can remediate all of these gaps and imbalances. Recognizing this fact, this volume tries to provide an essential, foundational level of information in the most relevant of these de-emphasized or omitted areas in ways that are both interesting and challenging.

THIS BOOK

Primary goals of this book are as follows:

1. To introduce interested people to the state of current knowledge and understanding in three active major subareas of comparative animal locomotion: swimming, natural flight, and terrestrial locomotion.
2. To present both the broad subjects and the specific fields as parts of an overall scientific effort to understand the organization, structure, function, and history of the living world in the context of a modern understanding of evolutionary biology.
3. To help people who come to this subject area from nonbiological backgrounds to gain better understanding and perspective with respect to the intellectual position of biomedically oriented studies of humans and of model systems that illuminate important human-related questions. We (humans) are the way we are and do what we do in large part because of our evolutionary history. This book discusses many biomedically important topics, but it approaches them from the perspective of how the biodiversity of animals survive and function in the natural world.
4. To introduce people to some of the biophysical-, biomechanical-, and bioengineering-related aspects of the tree of life, with examples selected from the diversity of organisms that share our planet with us.
5. To provide selected, and hopefully provocative and stimulating, examples of ways in which biophysics, biomechanics, and bioengineering can help to develop new technologies and products based on studies of living organisms viewed from the perspectives of biomimetics and bioinspired design.

The past 20 years has seen remarkable growth in interest and research literature in all major areas of biomechanics, biophysics, and bioengineering; thus, we believe there is a need for more quantitative, physical sciences, and engineering-oriented books like this one.

To achieve that goal, the organization and content of this book reflect several important trade-offs:

1. Although less comprehensive in scope than some current books, subject areas included are discussed in greater depth and at more advanced levels.
2. The evolutionary and biodiversity-oriented (cladistic) framework presented has rarely, if ever, been used in previous textbooks in bioengineering.
3. Students interested in areas not discussed in this volume are best served by referring to more specialized books and review articles on those topics. The reference sections in this book include useful referrals.

This book represents a four-person team effort devoted to providing authoritative and in-depth treatments of the included subject areas. Each discussion is based on the research interests and activities of the respective co-author(s). An important result of this approach is that it exposes students to varied theoretical and stylistic approaches to subject matter. The contents of most chapters are based on courses taught by their author(s).

Recommended background for people using this book includes knowledge of basic organismic (including evolutionary) biology, some organismic or organ system animal physiology, and basic physics and chemistry. Mathematical background should include 2 years of university-level calculus directed toward students in the physical sciences and engineering (as taught at many research universities), including vector calculus, linear algebra, differential equations, and complex analysis.

Major features of this book are as follows:

1. It is selective and not intended to be encyclopedic in its coverage of its subject fields.

2. Treatment of each major subject area is structured around discussions of basic physical principles and then of selected adaptations. It emphasizes the important underlying theoretical and mathematical foundations of the areas covered and illustrates the real-world manifestations of these foundations with selected examples of processes and adaptations occurring primarily in living animals. Discussions of fossil organisms are included where relevant.
3. Primary contexts for all discussions are biodiversity-based, comparative, evolutionary, environmental, ecological, and behavioral.
4. Levels of structural and organizational complexity discussed are mostly at the macroscopic organismic and organ system levels.
5. Human-related materials are included where they best fit these other contexts.
6. Occasional limited mentions of microorganisms and plants are included.