There is often confusion over the meaning and usage of terms such as efficiency, economy, effectiveness, optimization and perfection in biology. This book defines and discusses these concepts within a broad evolutionary perspective and considers how evolutionary pressures can affect the economy and efficiency of animals. Chapters consider biomaterials, skeletal systems, muscular function, aquatic and terrestrial locomotion, respiratory and cardiovascular systems. The result is a book of interest to all biologists, and particularly to those working in the fields of comparative physiology and evolutionary biology.

Efficiency and economy in animal physiology

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Edited by

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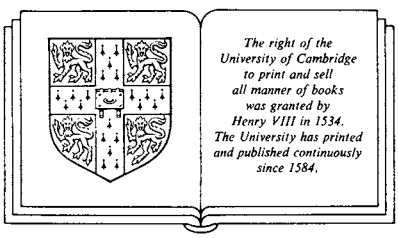

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PREFACE

This book is based on the proceedings of a symposium sponsored by the American Society of Zoologists, held during the society's San Francisco meeting (27–30 December 1988). Arguably, most physiological symposia focus, with varing degree of specificity, on issues within a classical division of the subject. This traditional approach has been, and continues to be, worthwhile and fruitful. However, the impetus here was to take a general theme (efficiency) and explore it broadly from a variety of perspectives and fields. The general consensus of opinion of the participants and audience at the San Francisco meeting was that the symposium was successful and worthy of publication. The resulting book consists of ten chapters (contributed by the symposium speakers) which vary somewhat in depth of coverage, length, style, and organization. This reflects a conscious decision on my part not to strive for uniformity through 'heavy handed' editing. A brief outline of the book's structure and content follows.

Chapter 1 (C. Gans) establishes definitions for a variety of terms (e.g. adequacy, efficiency, optima, perfection) that are employed by some authors in subsequent chapters. Gans discusses these concepts in the context of evolutionary biology, bearing on adaptation, development, and speciation. This issue is returned to in Chapter 10 (G.V. Lauder) where it is argued that concepts of efficiency may be used in integrating the discipline of physiology with historical biology. In Chapter 2 (R.W. Blake) the influence of the choice of formalism, interpreting high and low values, and the relevance of laboratory results to field situations are considered for efficiency criteria in physiological systems. Blake points out that some constraints on efficiency are set by physical and biological factors,

and this is explored more fully for the case of aquatic propulsion by T.L. Daniel in Chapter 6. Daniel discusses thrust generation in swimming organisms of different size, morphological design, and kinematics in relation to efficiency for steady and unsteady motions. Physiological limits to performance associated with muscle function, and energy storage and dissipation in muscle are also discussed. C.J. Pennycuick (Chapter 3) relates muscle efficiency to contraction frequency, and in a novel analysis derives muscle efficiency from Huxley's equations for the sliding filament model. In Chapter 4 J.M. Gosline reviews efficiency criteria for biomaterials. He focuses on elastic efficiency (resilience) showing that this parameter need not be maximized for effective function in some cases. The efficiency of skeletal design is discussed by A. Biewener and J. Bertram in Chapter 5. They point out that efficiency (defined as strength per unit mass) is only one of a variety of factors necessary to evaluate the performance of skeletons. The importance of historical constraints on skeletal form and function are also discussed. Complementing Daniel's review of efficiency criteria for aquatic locomotion (Chapter 6), R. Full considers the efficiency of terrestrial movement in Chapter 7. He reviews a variety of mechanical efficiency criteria and emphasizes the importance of considering other factors (e.g. endurance, stability, acceleration) in evaluating the performance of terrestrial locomotion. In addition, the economy (cost of transport) of movement is discussed in relation to body form. R. Full shows that whole animal mechanical efficiency is highly variable and not simply equal to the efficiency of isolated muscle. Chapters 8 and 9 deal with efficiency criteria for the respiratory (Milsom, Chapter 8) and cardiovascular (Jones, Chapter 9) systems. Milsom shows that the overall efficiency of the respiratory systems is a complex function of the anatomy of the gas exchange organs, mechanics of the respiratory pumps and their pattern of ventilation. In the final chapter, G. Lauder (Chapter 10) emphasizes the utility of efficiency criteria in understanding the evolution of physiological systems when measured relative to an outgroup clade.

On behalf of all of the contributors to this book I would like to thank the American Society of Zoologists and the National Science Foundation for their financial support. Thanks are due to Mr A. MacDonnell and Mr H. de la Cueva for their assistance in editing the manuscript. I would also like to thank Dr Robin Smith and all at Cambridge University Press involved in the production of this book.

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