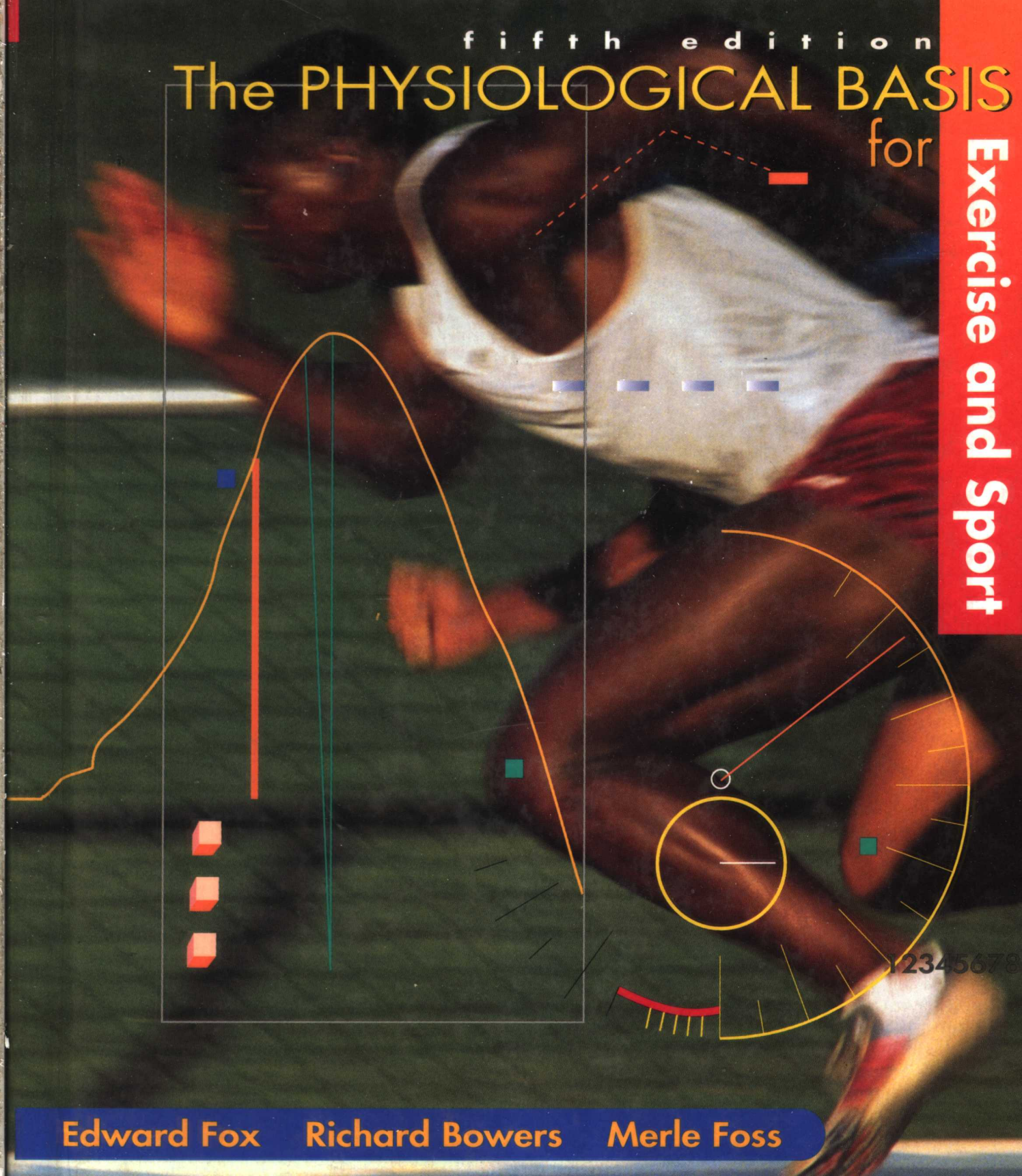
fifth edition
The PHYSIOLOGICAL BASIS for Exercise and Sport
Edward Fox
Richard Bowers
Merle Foss

fifth edition

The PHYSIOLOGICAL BASIS for Exercise and Sport

The Late Edward L. Fox

formerly of The Ohio State University

Richard W. Bowers

Bowling Green State University

Merle L. Foss

University of Michigan

12345678.....

WCB Brown & Benchmark PUBLISHERS

Madison, Wisconsin • Dubuque, Iowa

Book Team

Editor *Chris Rogers*
Developmental Editor *Scott Spoolman*
Production Editor *Kay J. Brimeyer*
Designer *Jeff Storm*
Art Editor *Kathleen M. Huinker*
Photo Editor *Carol A. Judge*
Permissions Editor *Mavis M. Oeth*
Visuals/Design Developmental Consultant *Marilyn A. Phelps*
Visuals/Design Freelance Specialist *Mary L. Christianson*
Publishing Services Specialist *Sherry Padden*
Marketing Manager *Pamela S. Cooper*
Advertising Manager *Jodi Rymer*

Brown & Benchmark
A Division of Wm. C. Brown Communications, Inc.

Vice President and General Manager *Thomas E. Doran*
Editor in Chief *Edgar J. Laube*
Executive Editor *Ed Bartell*
Executive Editor *Stan Stoga*
National Sales Manager *Eric Ziegler*
Director of CourseResource *Kathy Law Laube*
Director of CourseSystems *Chris Rogers*
Director of Marketing *Sue Simon*
Director of Production *Vickie Putman Caughron*
Imaging Group Manager *Chuck Carpenter*
Manager of Visuals and Design *Faye M. Schilling*
Design Manager *Jac Tilton*
Art Manager *Janice Roerig*
Permissions/Records Manager *Connie Allendorf*

WCB **Wm. C. Brown Communications, Inc.**

President and Chief Executive Officer *G. Franklin Lewis*
Corporate Vice President, President of WCB Manufacturing *Roger Meyer*
Vice President and Chief Financial Officer *Robert Chesterman*

The credits section for this book begins on page 695 and is considered an extension of the copyright page.

Cover © Lori Adamski-Peek/Tony Stone Worldwide

Copyedited by Kathy Pruno

A Times Mirror Company

Library of Congress Catalog Card Number: 92-71097

ISBN 0-697-12626-9

Printed in the United States of America by Wm. C. Brown Communications, Inc., 2460 Kerper Boulevard, Dubuque, IA 52001

10 9 8 7 6 5 4

Dedicated

to

our loving wives

Carolyn Bowers and Peg Foss

who have each found their

own successes in exercise and sport

□ □ □

PREFACE

If you are a past user of the text, the first thing that you will notice is the title change. We have decided to re-title the text, *The Physiological Basis for Exercise and Sport.* The knowledge base and application of concepts have gone well beyond that which existed in 1971 when the first edition of the text was written. The explosion in applications beyond physical education and athletics has given the text a wider audience. While retaining much of the basic knowledge from earlier editions, we have attempted to weave newer applications into the fifth edition.

As with the previous edition, we have been conscious of the legacy that Edward L. Fox (1938–1983) left in the form of this text. We have again tried to preserve the clarity of presentation, the writing style, and tone that have been hallmarks of previous editions. Most importantly, one of our goals has been to write the text for the student rather than for other professors.

This text has been written not only for future physical educators and coaches, but also for students in various other health professions, including physical therapy, occupational therapy, the fitness area, and other applicable fields. Another goal of ours is to provide, through the materials in this text, concepts for safe and sensible conduct of not only sport and physical education programs but also any exercise-based programs.

Major topical additions and updates include material in metabolism, muscle adaptations with training, recovery from exercise, exercise and training for health and fitness, and body composition concepts. Further, chapters 16 and 17 from the previous edition have been combined into a single chapter. While we have not made a wholesale conversion to the International System of Units (Systeme International d'unites) for units of measurement, we have started the process by making reference to conversion units throughout the text. Selected new illustrations have been added and all of the artwork has, once again, been reworked. Further, for the first time, approximately 50 transparencies and an instructors manual have been added to facilitate the teaching process.

It is our hope that students will be challenged to learn the scientific, or physiological, reasons for training and exercise. In the 1970s, we could not yet say that regular physical activity and being physically fit played a role in longevity. Today, we can. Further, it is our hope that students can themselves eventually challenge current concepts and bring forth new and insightful information.

We would like to thank Scott Spoolman and the staff of Brown and Benchmark for their combined guidance, encouragement, and support throughout the revision process. We also would like to thank

Priscilla M. Clarkson
University of Massachusetts, Amherst
William Floyd
University of Wisconsin–LaCrosse
Roberta Pohlman
Wright State University
Sandra Kay Burrus
Indiana University
Thomas Balon
University of Iowa

for their most helpful and critical review of the manuscript.

A special note of thanks goes to Dr. Robert Staron (Ohio University) and to Dr. J. E. Lindsay Carter (San Diego State University) for their special contributions to the areas of skeletal muscular response to training and somatotype concepts. We again want to acknowledge the contribution of Ann Snyder (University of Wisconsin–Milwaukee) for her critique of the chapter on the female athlete.

Thanks also goes to Dr. Fredrick C. "Fritz" Hagerman for support during a critical time in the preparation of the manuscript for this edition of the text. His enthusiasm and dedication are infectious.

Richard W. Bowers
Merle L. Foss

CONTENTS

SECTION 5

Environmental Considerations

SECTION 6

Nutrition and Body Weight Control

The PHYSIOLOGICAL BASIS for Exercise and Sport

Introduction to Sports Medicine, Exercise Physiology, and Kinesiology

1

Today more than ever before it is necessary for physical educators, coaches, trainers, and fitness instructors to recognize the vital part *science* plays in the successful conduct of physical education, athletic, and activity programs. Over the past 30 years the number of exercise physiology laboratories has increased tremendously. As a result much new knowledge dealing with how best to train athletic teams and to develop fitness for health has appeared in the scientific literature.

Further evidence of advancement in the scientific area of physical education and athletics was the formation of the American College of Sports Medicine (ACSM) in 1954. The college membership is made up of physical educators, athletic trainers, coaches, exercise physiologists, physicians, nutritionists, and numerous other interested professional groups. Membership in the college rose to 3000 from 1954 to 1975, and then doubled to over 6000 between 1975 and 1978. Now with over 13,000 members, the American College of Sports Medicine is the largest and most influential sports medicine group in the world. In 1984, the ACSM National Center was moved from Madison, Wisconsin, to Indianapolis, Indiana. There also are ten regional chapters located throughout the United States. The national ACSM organization meets once a year, at which time research papers covering all aspects of the science of sports and exercise are presented. *Medicine and Science in Sports and Exercise,* published monthly by the College, is an international journal containing research articles dealing with all facets of sports medicine. The ACSM also publishes position stands and opinion statements on specific topics and public issues and offers certification programs for Exercise Leaders, Exercise Test Technologists, Exercise Specialists, and Exercise Program Directors as well as Health Fitness Instructors and Health Fitness Directors.

Another example of the ever-increasing interest in sports medicine was the formation of the Committee on the Medical Aspects of Sports in 1959, an organization of the American Medical Association. This group does an excellent job in disseminating literature concerned with protecting the health of the athlete as well as holding seminars for coaches, trainers, and physicians.

The Association for Fitness in Business (AFB), formerly called the American Association of Fitness Directors in Business and Industry, was organized in 1974 to meet the growing need of a variety of professionals and their support staffs who began to develop worksite fitness and health promotion programs. The AFB holds a national conference each year and also has developed a network of ten regional chapters and international affiliates to disseminate information regarding promotion and management of programs in corporate, hospital, private, and community settings.

Still other organizations about which the informed student should be aware are the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD), the United States Olympic Committee (USOC), the President's Council on Physical Fitness and Sports (President's Council), and the Federation Internationale de Medicine Sportive

(FIMS). Student membership is available in ACSM, AFB, and AAHPERD, whereas appointment to the other groups is necessary for direct involvement.

For you to contribute to the best of your ability to all aspects of physical education, athletics, and fitness leadership will require a good understanding of the available scientific knowledge. Such understanding will not only result in better teams and better programs of activities, but also enable you to guard the health of your students, athletes, and clients, which is one of your primary responsibilities. Then too, knowing the reasons *why* you select a particular approach for accomplishing a specific task immediately establishes you as a professional rather than a technician.

The recent and rapid expansion of knowledge and interest in sports medicine requires that you learn much more factual and technical information than your predecessors. At the same time, you are favored by having a greater number of career opportunities open to you. There are few career tracks today that offer more variety, personal challenge, and opportunity for service than those related to the educational, scientific, and clinical aspects of sports medicine and exercise science.

The major concepts to be learned from this chapter are as follows:

- Comprehension of exercise physiology is important for physical educators, coaches, trainers, and fitness instructors.
- *Sports medicine* is a term that refers to all aspects of sport and exercise science.
- Because of recent research and an upsurge of interest in physical fitness, health, and wellness, today's young professionals are faced with increased learning challenges and career opportunities.
- *Exercise physiology* is an aspect of kinesiology and sports medicine that involves the study of how the body, from a functional standpoint, responds, adjusts, and adapts to exercise.
- *Kinesiology* is a broad, umbrella term that means the scientific study of human movement. This includes such aspects of study as exercise physiology, motor learning/control, and biomechanics.
- There are reasons to be in awe of the performance capabilities of the human body when viewed as a working "machine."
- Both the older *systems approach* and the more recent emphasis on *cellular biology* are important to better understanding its functions and limitations. This is the challenge of the future.

What Are Sports Medicine, Exercise Physiology, and Kinesiology?

In the preceding discussion, the terms *sports medicine* and *exercise physiology* were mentioned several times. These terms may have different meanings to different people, so let's define them here. In the United States, sports medicine is an all-encompassing term that refers to all aspects, not just medical, of sport and exercise. Examples of such aspects would be (1) athletic medicine, (2) biomechanics, (3) clinical medicine, (4) growth and development, (5) psychology and sociology, (6) nutrition, (7) motor control, and (8) physiology. This latter aspect is synonymous with exercise physiology or the physiology of exercise. As the term implies, this aspect of sports medicine involves the study of how the body, from a functional standpoint, responds, adjusts, and adapts to exercise. This includes acute exercise (i.e., single bouts of exercise) as well as chronic or prolonged exercise, as is the case with exercise training. In other words, exercise physiology provides the physiological basis of physical education, fitness, and athletic programs.

The term *kinesiology* has undergone some changes in usage and deserves some clarification of its current definition. Its root meaning is from the Greek word *kinein* (to move), which is combined with -logy from the Greek word *-logia,* which means a science, doctrine, or theory of some topic. For our common use, *kinesiology means the scientific study of movement.* Kinesiology, at one time, was taught as a single course within most college and university physical education curriculums and included material now covered in biomechanics classes. Another change in the use of the term *kinesiology* is more widespread. During the late 1980s, many Physical Education units at institutions of higher learning in the United States and Canada changed their names to Kinesiology or some derivation thereof. This elevated the term to a higher level of usage and denoted a broader definition. It also placed an important burden on physical education practitioners to be certain that the ever-important traditional aspects of this curriculum were not lost in the transition process.

The Body as a Machine

Although humanists might take issue with an engineering approach that views the body as a "working machine," doing so has a number of advantages and justifications. First, the learner can relate physiological functions to the workings of other devices that they may have experienced in the more observable world of machines. For example, a basic understanding of how fluids are circulated under pressure in the closed cooling system of a car allows an easier appreciation of how the body adjusts to remain cool during the performance of work. Likewise, a basic knowledge of cellular metabolic functions allows a better understanding of the production sites and quantities of useful and bothersome heat produced during exercise. A combination of these thought processes allows the well-informed analyst to diagnose and reasonably predict the effects of any compromised function by parts common to both machines. By way of example, would covering the radiator of a car and the skin of a human body with blankets on a hot day not have a similar effect on core temperature if their "motors" were kept running? The temperatures of both "machines" would increase primarily because of the continued production and circulation of nonusable heat in unfavorable conditions for dissipating the heat load.

The foregoing analogy makes the point that a knowledge of both systems physiology and cellular biology are important to our contemporary understanding of how the body works. Although most of the systems aspects have been worked out and are reasonably well understood, the future of exercise physiology, as an academic discipline, resides in our understanding of cellular and subcellular *mechanisms* (note this choice of words which is used throughout biology). For this reason, students are encouraged to think at both levels but to ever increase their depth of knowledge about cellular processes.

With this in mind and going back to thoughts of the human body as a machine, there may be little wonder why many exercise scientists are awed by the human body's potential performance capabilities. World records substantiate that it allows both impressive sprint (100 meters in about 10 seconds) and long-distance