

INTRODUCTION

A View of the Past: Exercise Physiology: Roots and Historical Perspectives **xv**

Interview with Dr. Charles M. Tipton

PART ONE

EXERCISE PHYSIOLOGY **1**

SECTION 1 Nutrition: The Base for Human Performance **3**

Interview with Dr. David L. Costill

CHAPTER 1 Carbohydrates, Lipids, and Proteins **7**

PART 1 • CARBOHYDRATES **8**

- Kinds and Sources of Carbohydrates 8
- Recommended Intake of Carbohydrates 14
- Role of Carbohydrates in The Body 14
- Carbohydrate Dynamics During Physical Activity 15

PART 2 • LIPIDS **18**

- The Nature of Lipids 18
- Kinds and Sources of Lipids 18
- Recommended Lipid Intake 25
- Role of Lipid in The Body 26
- Fat Dynamics During Physical Activity 27

PART 3 • PROTEINS **30**

- The Nature of Proteins 30
- Kinds of Protein 30
- Recommended Protein Intake 32
- Protein's Role in The Body 33
- Dynamics of Protein Metabolism 33
- Nitrogen Balance 36
- Protein Dynamics During Physical Activity 37

CHAPTER 2 Vitamins, Minerals, and Water **41**

PART 1 • VITAMINS **42**

- The Nature of Vitamins 42
- Kinds of Vitamins 42
- Role of Vitamins 42
- Defining Nutrient Needs 43
- Physical Activity, Free Radicals, and Antioxidants 49
- Does Vitamin Supplementation Provide a Competitive Edge? 51

PART 2 • MINERALS **53**

- The Nature of Minerals 53
- Role of Minerals in The Body 53
- Calcium 57
- The Female Athlete Triad: An Unexpected Problem for Women Who Train Intensely 61
- Phosphorus 63
- Magnesium 63
- Iron 64
- Sodium, Potassium, and Chlorine 67
- Minerals and Exercise Performance 68

PART 3 • WATER **72**

- The Body's Water Content 72

- Water Balance: Intake Versus Output 74
- Water Requirement in Physical Activity 75

CHAPTER 3 Optimal Nutrition for Physical Activity **79**

- Nutrient Intake Among the Physically Active 80
- The Essentials of Good Nutrition 85
- Myplate: The Healthy Eating Guide 85
- Physical Activity and Food Intake 87
- Precompetition Meal 92
- Carbohydrate Feedings Prior To, During, and in Recovery from Physical Activity 94
- Glucose Feedings, Electrolytes, and Water Uptake 99

SECTION 2 Energy for Physical Activity **105**

Interview with Dr. John O. Holloszy

CHAPTER 4 Energy Value of Food **109**

- Measurement of Food Energy 110

CHAPTER 5 Introduction to Energy Transfer **117**

- Energy—The Capacity for Work 118
- Interconversions of Energy 120
- Biologic Work in Humans 121
- Enzymes and Coenzymes Alter the Rate of Energy Release 124
- Hydrolysis and Condensation: The Basis for Digestion and Synthesis 126

CHAPTER 6 Energy Transfer in the Body **133**

- PART 1 • PHOSPHATE BOND ENERGY** **134**
 - Adenosine Triphosphate: The Energy Currency 134
 - Phosphocreatine: The Energy Reservoir 136
 - Cellular Oxidation 137
 - Oxygen's Role in Energy Metabolism 140
- PART 2 • ENERGY RELEASE FROM MACRONUTRIENTS** **141**
 - Energy Release from Carbohydrate 141
 - Energy Release from Fat 150
 - Energy Release from Protein 156
 - The Metabolic Mill: Interrelationships Among Carbohydrate, Fat, and Protein Metabolism 156

CHAPTER 7 Energy Transfer During Physical Activity **161**

- Immediate Energy: The ATP-PCr System 162
- Short-Term Glycolytic (Lactate-Forming) Energy System 162
- Long-Term Energy: The Aerobic System 163
- Energy Spectrum of Physical Activity 167
- Oxygen Consumption During Recovery 168

CHAPTER 8 Measurement of Human Energy Expenditure **177**

- Measuring The Body's Heat Production 178
- Doubly Labeled Water Technique 184
- Respiratory Quotient 185
- Respiratory Exchange Ratio (RER) 189

CHAPTER 9

Human Energy Expenditure During Rest and Physical Activity 191

- PART 1 • ENERGY EXPENDITURE AT REST 192**
 Basal and Resting Metabolic Rate 192
 Metabolic Size Concept 192
 Metabolic Rates of Humans: Age and Gender Comparisons 193
 Five Factors That Affect Total Daily Energy Expenditure 196

- PART 2 • ENERGY EXPENDITURE DURING PHYSICAL ACTIVITY 199**
 Classification of Physical Activities by Energy Expenditure 199
 The Met 200
 Daily Rates of Average Energy Expenditure 200
 Energy Cost of Household, Industrial, and Recreational Activities 202
 Heart Rate to Estimate Energy Expenditure 202

CHAPTER 10

Energy Expenditure During Walking, Jogging, Running, and Swimming 205

- Gross Versus Net Energy Expenditure 206
 Economy of Human Movement 206
 Energy Expenditure During Walking 208
 Energy Expenditure During Running 212
 Swimming 220

CHAPTER 11

Individual Differences and Measurement of Energy Capacities 227

- Specificity Versus Generality of Metabolic Capacity and Exercise Performance 228
 Overview of Energy-Transfer Capacity During Exercise 228
 Anaerobic Energy Transfer: The Immediate and Short-Term Energy Systems 228
 Aerobic Energy: The Long-Term Energy System 236

SECTION 3 Aerobic Systems of Energy Delivery and Utilization 249

Interview with Dr. Loring B. Rowell

CHAPTER 12

Pulmonary Structure and Function 253

- Surface Area and Gas Exchange 254
 Anatomy of Ventilation 254
 Mechanics of Ventilation 255
 Lung Volumes and Capacities 258
 Lung Function, Aerobic Fitness, and Physical Performance 261
 Pulmonary Ventilation 261
 Variations From Normal Breathing Patterns 265
 The Respiratory Tract During Cold-Weather Physical Activity 267

CHAPTER 13

Gas Exchange and Transport 269

- PART 1 • GASEOUS EXCHANGE IN THE LUNGS AND TISSUES 270**
 Concentrations and Partial Pressures of Respired Gases 270
 Gas Movement in Air and Fluids 271
 Gas Exchange in The Lungs and Tissues 272

- PART 2 • OXYGEN TRANSPORT 275**
 Oxygen Transport in Blood 275

- PART 3 • CARBON DIOXIDE TRANSPORT 282**
 Carbon Dioxide Transport in The Blood 282

CHAPTER 14

Dynamics of Pulmonary Ventilation 285

- PART 1 • REGULATION OF PULMONARY VENTILATION 286**
 Ventilatory Control 286
 Regulation of Ventilation During Physical Activity 288

- PART 2 • PULMONARY VENTILATION DURING PHYSICAL ACTIVITY 290**
 Ventilation and Energy Demands During Physical Activity 290
 Energy Cost of Breathing 295
 Does Ventilation Limit Aerobic Power and Endurance Performance? 296

PART 3 • ACID-BASE REGULATION 298

- Buffering 298
 Physiologic Buffers 300
 Effects of Intense Physical Activity 301

CHAPTER 15

The Cardiovascular System 303

- Cardiovascular System Components 304
 Hypertension 315
 Blood Pressure Response to Physical Activity 318
 The Heart's Blood Supply 320
 Myocardial Metabolism 322

CHAPTER 16

Cardiovascular Regulation and Integration 325

- Intrinsic Regulation of Heart Rate 326
 Extrinsic Regulation of Heart Rate and Circulation 327
 Distribution of Blood 333
 Integrative Response During Physical Activity 336
 Physical Activity After Cardiac Transplantation 337

CHAPTER 17

Functional Capacity of the Cardiovascular System 341

- Cardiac Output 342
 Cardiac Output at Rest 343
 Cardiac Output During Physical Activity 344
 Cardiac Output Distribution 347
 Cardiac Output and Oxygen Transport 348
 Cardiovascular Adjustments to Upper-Body Exercise 352

CHAPTER 18

Skeletal Muscle: Structure and Function 355

- Gross Structure of Skeletal Muscle 356
 Skeletal Muscle Ultrastructure 360
 Muscle Fiber Alignment 362
 Actin-Myosin Orientation 366
 Chemical and Mechanical Events During Muscle Action and Relaxation 367
 Muscle Fiber Type 374
 Genes That Define Skeletal Muscle Phenotype 379
 Fiber Type Differences Among Athletic Groups 379

CHAPTER 19

Neural Control of Human Movement 383

- Neuromotor System Organization 384
 Nerve Supply to Muscle 391
 Motor Unit Functional Characteristics 396
 Receptors in Muscles, Joints, and Tendons: The Proprioceptors 400

CHAPTER 20
The Endocrine System: Organization and Acute and Chronic Responses to Physical Activity **407**

- Endocrine System Overview 408
- Endocrine System Organization 408
- Resting and Exercise-Induced Endocrine Secretions 414
- Gonadal Hormones 425
- Exercise Training and Endocrine Function 440
- Resistance Training and Endocrine Function 445
- Opioid Peptides and Physical Activity 447
- Physical Activity, Infectious Illness, Cancer, and Immune Response 449

PART TWO
APPLIED EXERCISE PHYSIOLOGY **455**

SECTION 4 **Enhancement of Energy Transfer Capacity** **457**

Interview with Bengt Saltin

CHAPTER 21
Training for Anaerobic and Aerobic Power **461**

- Exercise Training Principles 462
- How Exercise Training Impacts the Anaerobic System 464
- Anaerobic System Changes with Training 464
- How Training Impacts the Aerobic System 464
- Factors That Affect Aerobic Training Responses 477
- How Long Before Improvements Occur? 484
- Maintaining Gains in Aerobic Fitness 485
- Training Methods 486
- Overtraining: Too Much of a Good Thing 490
- Physical Activity During Pregnancy 491

CHAPTER 22
Muscular Strength: Training Muscles to Become Stronger **499**

PART 1 • STRENGTH MEASUREMENT AND RESISTANCE TRAINING **500**

- Objectives of Resistance Training 502
- Measurement of Muscle Strength 502
- Gender Differences in Muscle Strength 506
- Training Muscles to Become Stronger 509

PART 2 • STRUCTURAL AND FUNCTIONAL ADAPTATIONS TO RESISTANCE TRAINING **528**

- Factors That Modify the Expression of Human Strength 528
- Comparative Training Responses in Men and Women 535
- Detraining Effects on Muscle 536
- Metabolic Stress of Resistance Training 537
- Circuit Resistance Training 537
- Muscle Soreness and Stiffness 538

CHAPTER 23
Special Aids to Exercise Training and Performances **543**

- An Increasing Challenge To Fair Competition 544
- On the Horizon 548

PART 1 • PHARMACOLOGIC AGENTS FOR ERGOGENIC EFFECTS **548**

PART 2 • NONPHARMACOLOGIC APPROACHES FOR ERGOGENIC EFFECTS **571**

SECTION 5 **Exercise Performance and Environmental Stress** **593**

Interview with Barbara Drinkwater

CHAPTER 24
Physical Activity at Medium and High Altitude **597**

- The Stress of Altitude 598
- Acclimatization 600
- Metabolic, Physiologic, and Exercise Capacities at Altitude 608
- Altitude Training and Sea-Level Performance 610
- Combine Altitude Stay With Low-Altitude Training 611

CHAPTER 25
Exercise and Thermal Stress **615**

PART 1 • MECHANISMS OF THERMOREGULATION **616**

- Thermal Balance 616
- Hypothalamic Temperature Regulation 617
- Thermoregulation in Cold Stress: Heat Conservation and Heat Production 617
- Thermoregulation in Heat Stress: Heat Loss 618
- Effects of Clothing on Thermoregulation 621

PART 2 • THERMOREGULATION AND ENVIRONMENTAL HEAT STRESS DURING PHYSICAL ACTIVITY **626**

- Physical Activity in The Heat 626
- Maintaining Fluid Balance: Rehydration and Hyperhydration 630
- Factors That Modify Heat Tolerance 632
- Complications From Excessive Heat Stress 635

PART 3 • THERMOREGULATION AND ENVIRONMENTAL COLD STRESS DURING PHYSICAL ACTIVITY **637**

- Physical Activity in the Cold 637
- Cold Acclimatization 639
- How Cold Is Too Cold? 640

CHAPTER 26
Sport Diving **643**

- Diving History—Antiquity to the Present 644
- Pressure–Volume Relationships and Diving Depth 652
- Snorkeling and Breath-Hold Diving 653
- Scuba Diving 659
- Special Problems with Breathing Gases at High Pressures 661
- Dives to Exceptional Depths: Mixed-Gas Diving 667
- Energy Cost of Underwater Swimming 670

CHAPTER 27
Microgravity: The Last Frontier **673**

- The Weightless Environment 674
- Historical Overview of Aerospace Physiology and Medicine 680
- Modern Era 683
- Medical Evaluation for Astronaut Selection 686
- Bone 689
- Countermeasure Strategies 702
- Overview of Physiologic Responses to Spaceflight 714
- Nasa's New Vision for the Future of Space Exploration 715
- Practical Benefits from Space Biology Research 720
- Final Words 722

SECTION 6 **Body Composition, Energy Balance, and Weight Control** **727**

Interview with Dr. Claude Bouchard

CHAPTER 28
Body Composition Assessment **731**

- Overweight, Overfatness, and Obesity: No Unanimity for Terminology 732
- The Body Mass Index: A Popular Clinical Standard 733
- Composition of The Human Body 738
- Common Techniques to Assess Body Composition 742
- Average Percentage Body Fat 761
- Determining Goal Body Weight 762

CHAPTER 29
Physique, Performance, and Physical Activity **765**

- Physiques of Champion Athletes 766
- Upper Limit for Fat-Free Body Mass 784

CHAPTER 30
Overweight, Overfatness (Obesity), and Weight Control **787**

- PART 1 • OBESITY 788**
- Historical Perspective 788
 - Obesity Remains a Worldwide Epidemic 788
 - Increased Body Fat: A Progressive Long-Term Process 792
 - Genetics Influences Body Fat Accumulation 793
 - Physical Inactivity: A Crucial Component in Excessive Fat Accumulation 796
 - Health Risks of Excessive Body Fat 797
 - Criteria for Excessive Body Fat: How Fat Is Too Fat? 801

- PART 2 • PRINCIPLES OF WEIGHT CONTROL: DIET AND PHYSICAL ACTIVITY 808**
- Energy Balance: Input Versus Output 808
 - Dieting for Weight Control 809
 - Factors That Affect Weight Loss 819
 - Increased Physical Activity for Weight Control 820
 - Effectiveness of Regular Physical Activity 823
 - Weight Loss Recommendations for Wrestlers and Other Power Athletes 830
 - Gaining Weight: The Competitive Athlete's Dilemma 830

SECTION 7 **Exercise, Successful Aging, and Disease Prevention** **835**

Interview with Dr. Steven N. Blair

CHAPTER 31
Physical Activity, Health, and Aging **839**

- The Graying of America 840
- The New Gerontology 840

PART 1 • PHYSICAL ACTIVITY IN THE POPULATION 842

- Physical Activity Epidemiology 842

PART 2 • AGING AND PHYSIOLOGIC FUNCTION 848

- Age Trends 848
- Trainability and Age 858

PART 3 • PHYSICAL ACTIVITY, HEALTH, AND LONGEVITY 859

- Physical Activity, Health, and Longevity 859
- Regular Moderate Physical Activity Provides Significant Benefits 860

PART 4 • CORONARY HEART DISEASE 862

- Changes on the Cellular Level 862
- Coronary Heart Disease Risk Factors 864

CHAPTER 32
Clinical Exercise Physiology for Cancer, Cardiovascular, and Pulmonary Rehabilitation **877**

- The Exercise Physiologist in the Clinical Setting 878
- Training and Certification Programs for Professional Exercise Physiologists 880
- Clinical Applications of Exercise Physiology to Diverse Diseases and Disorders 880
- Oncology 880
- Cardiovascular Disease 884
- Assessing Cardiac Disease 892
- Stress Test Protocols 901
- Prescribing Physical Activity and Exercise 902
- Cardiac Rehabilitation 907
- Pulmonary Diseases 908
- Physical Activity and Asthma 916
- Neuromuscular Diseases, Disabilities, and Disorders 919
- Renal Disease 920
- Cognitive/Emotional Diseases and Disorders 921

SECTION 8 **On the Horizon** **925**

Interview with Dr. Frank W. Booth

CHAPTER 33
Molecular Biology: A New Vista for Exercise Physiology **929**

- Historical Tour of Molecular Biology 931
- Revolution in the Biologic Sciences 934
- The Human Genome 936
- Nucleic Acids 938
- How DNA Replicates 947
- Protein Synthesis: Transcription and Translation 950
- Mutations 968
- New Horizons in Molecular Biology 978
- Human Performance Research 1002
- Shaping the Future 1006

Index 1009