To my wife, Susan, for her patience and love; and my mother, Rita Wilkie, a proud member of “the greatest generation,” for her belief in higher education. Also to my daughter, Kathryn, my stepfather, the late William P. Wilkie, and my father, the late Joseph Medeiros, for their support and love through the years.

–D.M.M.

To my children: Gage and Bryn for your love, patience, and support. Also, to my father, Dave, and nephew, Jack, as well as eternal inspiration from my brother, David, and my mother, Carol.

–R.W.
Brief Contents

Preface xiii
Acknowledgments xvi
About the Authors xvii

Chapter 1 Foundations of the Human Body 1
Chapter 2 Digestion and Absorption 35
Chapter 3 Carbohydrates: Energy, Metabolism, and More 59
Chapter 4 Dietary Fiber: Digestion and Health 95
Chapter 5 Lipids: Fatty Acids, Triglycerides, Phospholipids, and Sterols 111
Chapter 6 Proteins and Amino Acids: Function, Quantity, and Quality 147
Chapter 7 Water 191
Chapter 8 Metabolism, Energy Balance, and Body Weight and Composition 207
Chapter 9 Nutrition, Exercise, and Athletic Performance 245
Chapter 10 Fat-Soluble Vitamins 273
Chapter 11 Water-Soluble Vitamins 305
Chapter 12 Major Minerals 345
Chapter 13 Minor Minerals 373
Chapter 14 Nutraceuticals and Functional Foods 419

Glossary 439
Index 455
## Contents

Preface .................................................. xiii  
Acknowledgments ................................. xvi  
About the Authors ................................. xvii  

### Chapter 1  Foundations of the Human Body .............. 1

- Introduction ......................................... 2  
- Elements and Molecules ........................... 2  
- Cell Structure and Organelles .................. 3  
  - Endoplasmic Reticulum .......................... 5  
  - Golgi Apparatus .................................. 6  
  - Endosomes, Lysosomes, and Peroxisomes 7  
  - Mitochondria ...................................... 7  
- The Nucleus and Genetic Aspects ................. 9  
  - DNA, RNA, and Genes ............................ 9  
- Protein Synthesis ................................. 12  
- Nutrition and Epigenetics ........................ 13  
- Electron Transport Chain and Oxidative Phosphorylation ................................. 13  
- Cellular Protein Functions ...................... 17  
  - Organelle and Cell Membrane Structure and Cell Receptors 17  
  - Enzymes .......................................... 18  
  - Cell Signaling .................................... 18  
  - Transport ......................................... 18  
  - Hormones ........................................ 19  
- Tissue ............................................... 21  
- Organ Systems ..................................... 22  
  - Bone and the Skeleton ......................... 22  
  - Nervous Tissue ................................... 23  
  - Skeletal Muscle ................................. 25  
  - Heart, Blood, and Circulation ............... 26  
  - Blood Pressure .................................. 29  
  - Renal System .................................... 29  
- Here's What You Have Learned ................... 32  
- Suggested Reading ................................. 32  

### Chapter 2  Digestion and Absorption .............. 35

- Introduction ......................................... 36  
- Gastrointestinal Anatomy ......................... 37  
  - Mouth ............................................ 37  
  - Stomach .......................................... 37  
  - Small Intestine .................................. 38  
  - Rugae, Villi, and Microvilli .................. 39  
  - Large Intestine (Colon) ....................... 39  
- Gastrointestinal Movement, Motility, and Neural Activity ................................. 40  
  - Smooth Muscle ................................... 40  
  - Smooth Muscle Excitation .................... 40  
- Enteric Nervous System ........................... 40  
  - Neurotransmitters ............................... 41  
  - Sympathetic and Parasympathetic Innervation ................................. 41  
- Digestive Tract Movements ....................... 41  
- Gastrointestinal Vasculature ..................... 42  
  - Hepatic Portal Vein ................................ 42  
- Gastrointestinal Endocrine and Paracrine Substances ................................. 42  
  - Gastrin .......................................... 42  
  - Cholecystokinin .................................. 43  
  - Secretin ......................................... 43  
  - Somatostatin ..................................... 43  
  - Gastric Inhibitory Polypeptide ............... 43  
  - Motilin .......................................... 44  
  - Peptide YY ........................................ 45  
  - Histamine ........................................ 45  
- Digestion and Absorption ......................... 47  
  - Phases of Digestion .............................. 47  
  - Oral Cavity ....................................... 48  
    - Saliva .......................................... 48  
    - Saliva Proteins: Enzymes and Mucus ........ 48  
    - Saliva Electrolytes ............................. 48  
  - Esophagus ........................................ 49  
    - Esophageal Sphincter ......................... 49  
  - Stomach ......................................... 49  
    - Gastric Juice and Hydrochloric Acid ........ 50  
    - Pepsin ......................................... 50
Contents

Amino Acids and Neurotransmitters .......................... 169
Disposal of Amino Acid Nitrogen ............................. 173
Urea Cycle ............................................... 173
Protein and Amino Acid Requirements ...................... 174
Protein ..................................................... 174
Amino Acids ............................................. 176
Amino Acid Inborn Errors of Metabolism .................... 178
Issues with Phenylalanine Metabolism: Phenylketonuria ................................. 178
Issues with Tyrosine Metabolism .............................. 178
Issues with Valine, Leucine, and Isoleucine Metabolism: Maple Syrup Urine Disease ................. 178
Issues with Methionine Metabolism .......................... 179
Issues with Tryptophan Metabolism ........................... 180
Issues with Lysine, Glycine, and Threonine Metabolism ......................................................... 181
Leucine and other Branched Chain Amino Acids as Related to Body Composition and Obesity ... 182
Protein Quality, Protein Excess, and Protein Deficiency .................................................. 184
Determination of Protein Intakes by Food Source Based on Limiting Amino Acids ............................ 184
Excess Dietary Protein ....................................... 185
Protein Undernutrition ..................................... 185
Here’s What You Have Learned ................................ 187
Suggested Reading .......................................... 190

Chapter 7 Water ................................. 191

Introduction ............................................. 192
Properties and Body Distribution of Water ..................... 192
Properties ............................................. 192
Distribution of Water in the Human Body ....................... 192
Sweat Water ............................................ 193
Urinary Water ......................................... 195
Water Balance ........................................... 199
Edema ................................................. 202
Mechanisms for Edema Formation ............................. 202
Edema in Pathologic States ................................ 202
Here’s What You Have Learned ................................ 205
Suggested Reading .......................................... 206

Chapter 8 Metabolism, Energy Balance, and Body Weight and Composition .................. 207

Introduction ............................................. 208
Total Energy Expenditure and Components ..................... 208
Measurement of Total Energy Expenditure ...................... 208
Direct or Human Calorimetry ................................ 209
Indirect Calorimetry ......................................... 209
Doubly Labeled Water ......................................... 210
Components of Energy Metabolism ............................ 211
Basal Metabolism (Resting Metabolism) ......................... 212
Thermic Effect of Activity ................................... 213
Thermic Effect of Food ...................................... 214
Adaptive Thermogenesis ...................................... 214
Metabolic States and Integrated Energy Metabolism ............. 216
Cellular and Tissue Metabolism ................................ 217
Obligate Glucose Utilization .................................. 218
Transitional Metabolic States .................................. 218
Metabolic Crossroads ....................................... 219
Fed State ................................................. 219
Early Refeeding ........................................... 219
Intermediate to Longer Fed State ............................... 221
Fasting .................................................. 221
Starvation ................................................. 223
Body Weight and Composition ................................ 224
Body Weight and Health ..................................... 224
Body Mass Index ........................................... 225
Active People, Body Weight, and Health ......................... 226
Body Composition .......................................... 226
Elements and Molecules ...................................... 226
Fat Mass and Fat-Free Mass ................................ 226
Body Water ............................................... 227
Minerals (Ash) ............................................ 227
Assessment of Body Composition ............................... 228
Body Densitometry ........................................... 228
Plethysmography ........................................... 229
Dual-Energy X-Ray Absorptiometry .............................. 230
Skinfold Assessment ........................................ 230
Bioelectrical Impedance Analysis ................................ 231
Regulation of Energy Intake, Storage, and Expenditure ............ 232
Futile Cycle Systems ........................................ 232
Chemical Mediators of Energy Homeostasis ...................... 233
Insulin .................................................. 233
Ghrelin .................................................. 233
Cholecystokinin ............................................ 233
Leptin .................................................. 233
Neuropeptide Y ........................................... 234
Galanin .................................................. 234
Here’s What You Have Learned ................................ 242
Suggested Reading .......................................... 243

Chapter 9 Nutrition, Exercise, and Athletic Performance .................. 245

Introduction ............................................. 246
Muscle and Exercise Basics .................................. 246
Muscle and Neuromuscular Junctions .......................... 247
Muscle Action Potentials .................................... 248
Sarcomeres and Contraction .................................. 248
Muscle Fiber Type ............................................. 249
Motor Unit Recruitment ...................................... 249
Exercise and Training Components ......................... 251
Muscle Adaptation to Strength Training .................... 251
Muscle Adaptation to Endurance Exercise ................... 252
Muscle Fiber Type and Endurance Adaptation ............. 252
Hormonal Adaptation to Acute and Chronic Exercise .... 252
Catecholamines .................................................. 252
Insulin and Glucagon ............................................ 255
Cortisol, Growth Hormone, and ACTH ...................... 255
Energy, Supportive Nutrients, and Exercise ............... 255
Creatine Phosphate ............................................. 255
Carbohydrate Metabolism and Exercise .................... 256
Muscle Carbohydrate Utilization ............................. 258
Maintaining Blood Glucose Levels During Exercise ...... 258
Cori Cycle ......................................................... 258
Alanine Cycle ..................................................... 259
Carbohydrate Oxidation During Exercise ................... 259
Glycogen Stores and Exercise ................................ 260
Carbohydrate Consumption Before, During, and After Exercise ............................................ 260
Carbohydrate Supercompensation (Glycogen Loading) .................................................. 261
Triglyceride and Fatty Acid Metabolism and Exercise .... 261
Fat Stores and Exercise ....................................... 261
Fatty Acid Oxidation in Muscle .................. ............... 263
Exercise and Fat Utilization ................................ 263
Fat Utilization After Exercise ................................ 263
Protein and Amino Acid Metabolism and Exercise ....... 263
Effect of Resistance Exercise and Postworkout Nutrition on Net Muscle Protein Turnover .......... 264
Effect of Endurance Exercise and Postworkout Nutrition on Net Muscle Protein Turnover .......... 265
Muscle Amino Acid Metabolism During Exercise ......... 266
General Protein Recommendations .......................... 266
Water and Exercise .............................................. 267
Dehydration and Performance ................................ 267
Water Recommendations for Athletic Performance ........ 267
Vitamins, Minerals, and Exercise .................................. 268
Here's What You Have Learned ............................... 270
Suggested Reading .............................................. 271

Chapter 10  Fat-Soluble Vitamins ............ 273
Introduction ......................................................... 274
Water and Fat Solubility ....................................... 274
Vitamin A .......................................................... 274
Dietary Sources of Vitamin A and Carotenoids ............ 275
Digestion and Absorption of Vitamin A and Carotenoids .................................................. 275
Implications of β-Carotene Cleavage and Associated Enzymes .................................................. 277
Plasma Transport of Vitamin A and Carotenoids ........ 278
Storage of Vitamin A and Cell Binding Proteins .......... 280
Functions of Vitamin A and Carotenoids .................. 280
Vision ............................................................... 280
Cell Differentiation .............................................. 281
Cancer ............................................................... 282
Glycoproteins ....................................................... 283
Reproduction ....................................................... 283
Antioxidant Capacity ............................................. 283
Other Functions .................................................... 283
Nutrient Relationships for Vitamin A and Carotenoids .................................................. 284
Excretion of Vitamin A and Carotenoids .................... 284
Recommended Levels of Vitamin A Intake ................. 284
Vitamin A Deficiency ............................................. 284
Vitamin A Toxicity ............................................... 284
Vitamin D .......................................................... 285
Sources of Vitamin D ............................................. 285
Absorption and Transport of Dietary Vitamin D ........ 285
Metabolism of Vitamin D ........................................ 286
Vitamin D Receptor and non-Genomic Functions .......... 287
Recommended Levels of Vitamin D Intake ................. 290
Vitamin D Deficiency ............................................. 291
Vitamin E .......................................................... 292
Food Sources of Vitamin E ..................................... 292
Vitamin E Absorption and Transport ......................... 293
Vitamin E Storage and Excretion ............................ 293
Function of Vitamin E ........................................... 294
Recommended Levels of Vitamin E Intake ................. 294
Vitamin E Deficiency ............................................. 296
Vitamin E and Other Fat Soluble Vitamins in the Development of Alzheimer's Disease ................. 296
Vitamin E Toxicity ............................................... 297
Vitamin K .......................................................... 297
Sources of Vitamin K ............................................. 297
Absorption and Transport of Vitamin K ..................... 298
Functions of Vitamin K ......................................... 298
The Vitamin K Cycle ............................................. 300
Recommended Levels of Vitamin K Intake ................. 300
Vitamin K Deficiency and Toxicity .......................... 301
Contents

Here's What You Have Learned .......................... 302
Suggested Reading ...................................... 303

Chapter 11 Water-Soluble Vitamins ............ 305

Introduction .............................................. 306
Vitamin C (Ascorbic Acid) .......................... 306
   Food Sources of Vitamin C ......................... 308
   Absorption of Vitamin C .......................... 308
   Functions of Vitamin C ........................... 309
   Recommended Levels of Vitamin C Intake ....... 309
   Vitamin C Deficiency .............................. 311
   Vitamin C Toxicity ................................ 311
Thiamin, Riboflavin, Niacin, and Vitamin B₁₂ .... 312
Thiamin (Vitamin B₁) ................................. 312
   Dietary Sources of Thiamin ....................... 313
   Digestion, Absorption, and Transport of Thiamin ........................................ 313
   Metabolism and Functions of Thiamin ......... 314
   Recommended Levels for Thiamin Intake ...... 316
   Thiamin Deficiency .................................. 316
   Thiamin Toxicity ..................................... 316
Riboflavin (Vitamin B₂) ............................... 316
   Dietary Sources of Riboflavin ................. 317
   Absorption and Transport of Riboflavin ....... 318
   Metabolism and Roles of Riboflavin .......... 318
   Recommended Levels of Riboflavin Intake .... 319
   Riboflavin Deficiency and Toxicity .......... 319
Niacin (Vitamin B₃) ..................................... 319
   Sources of Niacin ................................... 320
   Digestion and Absorption of Niacin ............ 321
   Metabolism and Functions of Niacin ........... 321
   Recommended Levels for Niacin Intake ....... 322
   Niacin Deficiency ................................... 322
   Pharmacologic Use of Niacin and Toxicity .... 322
Vitamin B₁₂ .............................................. 323
   Food Sources of Vitamin B₁₂ .................... 323
   Absorption of Vitamin B₁₂ ....................... 324
   Metabolism and Function of Vitamin B₁₂ .. 324
   Recommended Levels of Vitamin B₁₂ Intake . 327
   Vitamin B₁₂ Deficiency and Toxicity ........ 327
Folate, Vitamin B₁₂, Biotin, and Pantothenic Acid .. 328
Folic Acid (Folate) ...................................... 328
   Dietary Sources of Folate ......................... 328
   Absorption of Folate ............................... 328
   Metabolism and Functions of Folate .......... 329
   The Methyl–Folate Trap ............................ 331
   Recommended Levels for Folate Intake ....... 331
   Folate Deficiency and Toxicity ................. 331

Vitamin B₁₂ .............................................. 332
   Food Sources, Digestion, and Absorption of Vitamin B₁₂ ................................. 332
   Metabolism and Function of Vitamin B₁₂ ...................................... 333
   Recommended Levels of Vitamin B₁₂ Intake ........................................ 335
   Vitamin B₁₂ Deficiency ................................ 335
Biotin ..................................................... 337
   Sources of Biotin .................................... 337
   Digestion and Absorption of Biotin ............ 337
   Metabolism and Function of Biotin .......... 337
   Recommended Levels for Biotin Intake ...... 338
   Biotin Deficiency and Toxicity ................. 338
Pantothenic Acid ....................................... 338
   Food Sources of Pantothenic Acid ............. 339
   Digestion and Absorption of Pantothenic Acid ........................................ 339
   Metabolism and Function of Pantothenic Acid ......................................... 339
   Recommended Levels of Pantothenic Acid Intake ..................................... 340
   Deficiency and Toxicity of Pantothenic Acid ......................................... 340

Here's What You Have Learned ....................... 341
Suggested Reading ...................................... 342

Chapter 12 Major Minerals ....................... 345

Introduction .............................................. 346
Calcium .................................................. 346
   Dietary Calcium Sources .......................... 346
   Calcium Absorption ................................ 347
   Blood Calcium Levels and Homeostasis ....... 349
   Physiologic Roles of Calcium .................... 349
   Recommended Levels for Calcium Intake .... 353
   Calcium Deficiency ................................... 353
   Calcium Toxicity ..................................... 354
Phosphorus .............................................. 354
   Dietary Phosphorus Sources ..................... 354
   Digestion and Absorption of Phosphorus ...... 354
   Serum Phosphorus Levels and Homeostasis ... 355
   Physiologic Roles of Phosphorus ............... 356
   Recommended Levels of Phosphorus Intake .. 357
   Phosphorus Deficiency and Toxicity .......... 357
Magnesium .............................................. 357
   Dietary Magnesium Sources ..................... 357
   Magnesium Absorption ............................ 357
   Tissue Magnesium Content and Excretion .... 358
   Physiologic Roles of Magnesium ............... 359
   Recommended Levels for Magnesium Intake .. 360
   Deficiency and Toxicity of Magnesium ....... 360
Sodium, Chloride, and Potassium ............... 361
Dietary Sources of Sodium, Potassium, and Chloride ............... 361
Absorption of Sodium, Potassium, and Chloride ............... 362
Tissue, Urinary, and Sweat Content of Sodium, Potassium, and Chloride ............... 364
Physiologic Functions of Sodium, Potassium, and Chloride ............... 364
Recommended Levels of Intake for Sodium, Potassium, and Chloride ............... 365
Deficiency, Toxicity, and Health Concerns for Sodium, Potassium, and Chloride ............... 365
Sulfur ............................................. 368
Here’s What You Have Learned ....................... 369
Suggested Reading .................................... 370

Chapter 13  Minor Minerals ............... 373
Introduction ....................................... 374
Iron ................................................. 374
Dietary Sources of Iron and Iron Absorption ............... 374
   Dietary Iron and Availability ............... 374
   Dietary Components That Effect Absorption ............... 375
Iron Absorption Proteins and Mechanisms ............... 376
Iron Homeostasis .................................. 377
Metabolism and Function of Iron ............... 378
   Hemoglobin .................................. 378
   Iron Storage Proteins ....................... 378
   Transferrin .................................. 382
   Cellular Iron Control ....................... 382
   Enzyme Activity .............................. 382
   Recommended Levels of Intake for Iron ............... 383
   Iron Deficiency ................................ 383
   Iron Toxicity (Overload) ............... 383
   Conditions Under Which Iron Toxicity Occurs ............... 383
   Mechanism of Iron Toxicity ....................... 384
   Iron Toxicity and Diseases ............... 385
Zinc ................................................. 386
Dietary Zinc and Absorption ....................... 386
   Food Sources .................................. 386
   Dietary Factors That Affect Zinc Absorption ............... 386
Metabolism and Function of Zinc ............... 387
   Overall Metabolism ....................... 389
   Function of Zinc-Containing Proteins ............... 389
   Zinc Excretion ................................ 390
   Recommended Levels of Intake of Zinc ............... 390
Zinc Deficiency .................................. 391
Zinc Toxicity .................................... 391
Iodine .............................................. 391
Dietary Sources of Iodide ....................... 391
Absorption of Iodide ....................... 392
Metabolism and Function of Iodide ............... 392
Recommended Levels for Iodide Intake ............... 393
Iodide Deficiency ................................ 394
Copper ............................................. 395
Dietary Copper and Absorption ............... 395
   Food Sources .................................. 395
   Dietary Factors That Affect Copper Absorption ............... 395
   Metabolism and Function of Copper ............... 397
   Copper Transport Proteins and Cell Distribution ............... 399
   Recommended Levels of Intake for Copper ............... 399
   Copper Deficiency ....................... 399
   Genetic Anomalies Influencing Copper Status ............... 399
Selenium ........................................... 401
Dietary Selenium ....................... 401
Absorption of Selenium ....................... 401
Metabolism and Function of Selenium ............... 401
Selenium Incorporation into Proteins ............... 403
   Relationships Among Selenium and Other Nutrients ............... 404
   Recommended Levels of Intake for Selenium ............... 404
   Selenium Deficiency ....................... 404
   Selenium Toxicity ....................... 405
Fluoride ........................................... 406
Dietary Sources of Fluoride ............... 406
Absorption of Fluoride ....................... 406
Metabolism and Function of Fluoride ............... 407
   Recommended Levels for Fluoride Intake and Fluoride Toxicity Concerns ............... 408
Chromium ......................................... 408
Dietary Chromium ....................... 408
Absorption of Chromium ....................... 408
Metabolism and Function of Chromium ............... 409
   Recommended Levels of Intake for Chromium and Chromium Imbalance ............... 410
Manganese ........................................ 410
Dietary Sources of Manganese ............... 410
Absorption of Manganese ....................... 410
Metabolism and Function of Manganese ............... 410
   Recommended Levels of Intake and Manganese Imbalance ............... 411
Ultratrace Minerals ....................... 411
Cobalt ............................................ 411
Boron ............................................. 411
   Dietary Sources and Absorption of Boron ............... 411
   Metabolism and Function of Boron ............... 411
   Recommended Levels of Boron Intake and Boron Imbalance ............... 412
# Contents

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molybdenum</td>
<td>412</td>
</tr>
<tr>
<td>Dietary Sources and Absorption of Molybdenum</td>
<td>412</td>
</tr>
<tr>
<td>Metabolism and Function of Molybdenum</td>
<td>412</td>
</tr>
<tr>
<td>Recommended Levels of Molybdenum Intake and Imbalances</td>
<td>412</td>
</tr>
<tr>
<td>Vanadium</td>
<td>412</td>
</tr>
<tr>
<td>Dietary Sources and Absorption of Vanadium</td>
<td>413</td>
</tr>
<tr>
<td>Metabolism and Function of Vanadium</td>
<td>413</td>
</tr>
<tr>
<td>Recommended Levels of Vanadium Intake and Vanadium Imbalances</td>
<td>413</td>
</tr>
<tr>
<td>Nickel</td>
<td>413</td>
</tr>
<tr>
<td>Arsenic</td>
<td>413</td>
</tr>
<tr>
<td>Silicon</td>
<td>414</td>
</tr>
<tr>
<td>Here’s What You Have Learned</td>
<td>415</td>
</tr>
<tr>
<td>Suggested Reading</td>
<td>416</td>
</tr>
</tbody>
</table>

## Chapter 14 Nutraceuticals and Functional Foods 419

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>420</td>
</tr>
<tr>
<td>Defining Nutraceuticals and Functional Foods</td>
<td>420</td>
</tr>
<tr>
<td>Organizational Systems for Nutraceuticals and Functional Foods</td>
<td>421</td>
</tr>
<tr>
<td>Food Sources</td>
<td>421</td>
</tr>
<tr>
<td>Mechanism of Action</td>
<td>424</td>
</tr>
<tr>
<td>Health Claims</td>
<td>426</td>
</tr>
<tr>
<td>Organization of Nutraceuticals by Molecular Structure</td>
<td>428</td>
</tr>
<tr>
<td>Isoprenoid Derivatives (Terpenoids)</td>
<td>429</td>
</tr>
<tr>
<td>Phenolic Compounds</td>
<td>430</td>
</tr>
<tr>
<td>Carbohydrates and Carbohydrate Derivatives</td>
<td>433</td>
</tr>
<tr>
<td>Fatty Acids and Structural Lipids</td>
<td>434</td>
</tr>
<tr>
<td>Protein, Amino Acids, and Amino Acid Derivatives</td>
<td>434</td>
</tr>
<tr>
<td>Minerals</td>
<td>434</td>
</tr>
<tr>
<td>Microbes (Probiotics)</td>
<td>435</td>
</tr>
<tr>
<td>Here’s What You Have Learned</td>
<td>436</td>
</tr>
<tr>
<td>Suggested Reading</td>
<td>436</td>
</tr>
</tbody>
</table>

## Glossary 439

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index</td>
<td>455</td>
</tr>
</tbody>
</table>
In the preface to the last two editions, we posed the question, “Why a book on advanced human nutrition?” We responded that there was, and continues to be, a limited number of intermediate and advanced textbooks that detail why nutrients are important from a biochemical, physiologic, and molecular perspective. Today, the same shortage exists with the exception of Advanced Human Nutrition, whose initial success and adoptions exceeded our expectations.

Nutrition is a relatively new science, having evolved from several other scientific disciplines in the 20th century, and it continues to evolve today. The expansion of nutritional knowledge has been astounding. At the beginning of the 20th century, work conducted on food and food components was carried out by only a handful of scientists. As the 20th century progressed into its first few decades, many of the now well-known vitamins were discovered, their structures defined, and synthesis techniques developed. The metabolic mechanisms of macronutrients, particularly carbohydrates, lipids, and proteins, as well as energy metabolism in general, became the subject of intense research. The scientists who carried out such research came from a wide variety of disciplines, including organic and inorganic chemistry, agricultural chemistry, physiological chemistry, medicine, and animal sciences.

Originally, nutritional research was conducted by men and women simply for the love of science. Later, during the 1940s, the federal government took a more active role in scientific research, including nutrition. A high rate of rejection of military conscripts due to nutrition-related conditions prompted the establishment of the first U.S. Recommended Dietary Allowances (RDAs) in 1941. The RDAs have continued to be modified ever since; the Dietary Reference Intakes (DRIs) are the most recent version.

Research had been carried out with the indirect support of the federal government before the establishment of the RDAs. Nutrition research occurred at the land-grant institutions created by Abraham Lincoln in the 1860s through the Morrill Act. Modern nutrition evolved from agricultural, medical, and basic sciences into a discipline of its own. One of the early fathers of nutrition was a Kansas native, E. V. McCollum, who introduced the laboratory rat as a useful model in scientific research when studying vitamin A. Similarly, poultry scientists used chicks as a research model and made contributions to medical sciences. Much of the research on fiber began with animal scientists studying forages and feeds of livestock.

Research pertaining to minerals, their composition in the human diet, and their physiologic roles took form in the 20th century. Most of the earlier mineral research efforts focused on the major minerals, such as calcium, phosphorus, sodium, potassium, chloride, and magnesium. However, some work relating to the role of iron and the development of iron deficiency appeared in the earlier decades of the 20th century.

In the 1960s and 1970s, rapid advances in technology allowed for the ability to detect small quantities of trace minerals, such as selenium, zinc, copper, iron, fluoride, chromium, manganese, and iodine. Although the role of iodine in preventing goiters was already known, as was the potential for deleterious health effects from selenium toxicity, there was limited information on the role of many trace elements in optimizing human health. New technologies, such as neutron activation and atomic absorption spectrophotometry, allowed for detection of trace minerals in the part-per-billion or microgram-per-liter range. An explosion of knowledge regarding trace minerals occurred in the latter part of the 20th century.

As the 20th century came to a close, it was known that many nutrients functioned at the gene level, an idea that was unheard of at the beginning of the 20th century. Today, in the 21st century, new research was and is currently being carried out on the identification of new compounds in the diet, such as plant chemicals (phytochemicals). This area has led to the identification of compounds that promote health and prevent disease.

▶ Approach of this Text

In all of our previous editions, we sought to use a conversational approach in our writing to allow the reader to better grasp nutritional concepts, as opposed
to the more encyclopedic writing style common among advanced texts in science disciplines. We have been mindful of pedagogical tools that facilitate student learning. Many students have not mastered the optimal manner in which to read a textbook compared with literary works. A student needs to comprehend what he or she reads. Each chapter contains a series of “Before You Go On…” features in which the reader is asked a series of questions that can be answered from the material covered in the previous section. This tool can be used to help the student comprehend and focus on what is important in the text and to develop better study skills. The student is urged to answer each of the questions before proceeding with the next section of the chapter.

In the third edition of the text, two additional chapters were developed: one on fiber, which was previously part of the carbohydrates chapter; and a second on nutraceuticals and functional foods. Nutraceuticals—nutrients in foods that provide physiologic benefit beyond basic daily needs and/or support disease prevention or treatment—have been studied extensively in the last 15 years, and much has been discovered about their health benefits and mechanism of action. Fiber is one group of phytochemicals (plant-based nutraceuticals) where this information has expanded. Phytochemicals have been used to develop and produce functional foods either as supplements or as food. Thus, separate, in-depth attention to each of these still-evolving topics is needed for the student of nutrition to stay current. We include updated material to these two chapters.

As we did in previous editions, chapters are developed further by combining the scientific basis of why the basic nutrients are required with some applied concepts throughout. We accomplished this by integrating “Special Features” on focused topics to add depth to the chapters and to allow the student to view applications of the basic science. New special features have been added to this edition and existing ones have been updated based on new information in the scientific literature. The first edition was designed both as a textbook and a reference book, but the second, third, and now fourth editions are clearly designed as textbooks for college-level courses in human nutrition. The book assumes that students have completed courses in introductory nutrition, biochemistry, and some anatomy and physiology. Many students who are dietetics and nutrition majors, or who are beginning Master of Science degrees, will find this book appropriate for their level.

We have updated the figures and redesigned the text with the student in mind so that visual and textual, comprehension and study tools are available to reinforce concepts. This new edition has even more figures than the Third Edition; these were added after consultation with professors throughout the United States who are actively teaching advanced human nutrition courses, some of whom had been using the previous editions and some of whom had not. The goal here was to broaden the scope of concepts deemed significant for the student to comprehend. However, we took extra care to design the figures to balance simplicity with sufficient detail needed for an advanced treatment of the content.

Organization of this Text

Chapter 1 starts with an overview of the cell and examples of how nutrition can play a role in human health. Chapter 2 is aimed at a rigorous review of the anatomy and physiology of digestion. Both of these chapters are the foundation on which the rest of the book is built. Chapter 3 focuses on carbohydrates. However, as in the previous edition, fiber is discussed separately in Chapter 4. Chapters 5 and 6 focus on lipids and proteins, respectively, with the latter becoming one of the highest profile nutrient areas at this time. Chapter 7 focuses on water as a separate nutrient because it is present in our bodies in the largest quantity of all nutrients. Chapters 8 and 9 focus on energy, weight control, and exercise. Chapters 10 and 11 are detailed discussions of the fat-soluble and water-soluble vitamins, respectively. The text proceeds with two chapters on minerals: Chapter 12 on major minerals and Chapter 13 on minor minerals. We have added quite a bit of updated information to Chapters 10 through 13 in response to our peer reviewers. Chapter 14, titled, “Nutraceuticals and Functional Foods,” proved to be popular by adopters in the Third Edition. There have been scores of textbooks written on this topic. For this text, the focus was on understanding what constitutes nutraceuticals and functional foods, how they can be classified, and the nutrient categories of various types.

New to the Fourth Edition

Some of the most significant updates to the Fourth Edition include the following:

- Each chapter concludes with a section titled, “Clinical Insights,” in which a topic of clinical relevance is presented, linking the basic nutrition science covered in each chapter. Future clinicians
will find this useful in connecting the basic and applied elements of human nutrition and dietetics, better preparing each student for future courses in clinical nutrition.

- The use of gene editing (referred to as CRISPR) is discussed in Chapter 1, as this technology has the potential to correct genetic mutations that impact nutrition utilization and metabolism.
- Diseases of the gastrointestinal tract that have nutritional relevance in health and disease are now covered in Chapter 2.
- Bariatric surgery procedures used to treat obesity are discussed in Chapter 2, as their popularity has increased in tandem with some potential nutrition problems.
- The controversy of a possible contributing factor to the obesity epidemic due to increased linoleic acid intake is debated in one of the Special Features in Chapter 5.
- Alcohol, as related to disease, is covered in Chapter 5.
- The new American Heart Association and American College of Cardiology algorithms to determine the risk of a cardiac event are included in Chapter 5.
- Protein requirements have been challenged by some scientists as it relates to the RDA, and Chapter 6 incorporates coverage of this controversy. Newly available methods that determine nitrogen requirements compared with traditional nitrogen balance methods have led some to conclude that the RDA for protein should be increased significantly.
- Protein intake, physical activity, and sarcopenia are discussed in Chapter 6.
- Clinical signs and treatment of dehydration are covered in Chapter 7.
- Energy requirements, as estimated by several different algorithms used in clinical settings, are included in Chapter 8.
- Exercise recommendations for both endurance and weight-bearing exercises are featured in Chapter 9.
- The implications of β-carotene cleavage by different enzymes in the small intestine are covered in Chapter 10.
- Coverage of the role of fat-soluble vitamins, particularly vitamin E, in Alzheimer’s disease is included in Chapter 10.
- Transport mechanisms for water-soluble vitamins are discussed in Chapter 11.
- Novel roles of phosphorus in nutrition are featured in Chapter 12.

- The health-promoting effects of a group of phytochemicals—stilbenes—are now discussed in Chapter 14.

Instructor Resources

Comprehensive online teaching resources are available to instructors adopting the *Fourth Edition*, including the following:

- LMS-ready Test Bank, featuring more than 550 questions. This represents an increase of more than 100 questions compared with the previous edition. The level of rigor for each question is now indicated.
- Instructor’s Manual, including Learning Objectives, Key Terms, Chapter Outlines, Discussion Questions, Lecture Notes, and In-class Activities. These have been heavily revised from previous editions.
- Slides in PowerPoint format, containing more than 750 slides that can be adapted for in-class lectures. For each topic, sample lectures with PowerPoint slides are included to help save time for the instructor in preparation of class materials. These lectures can be modified easily for each instructor’s unique needs.
- Image Bank in PowerPoint format, compiling the figures appearing in this text.

In Conclusion

The order and content of information presented in this book are typical of the curricula at most academic institutions where nutrition and dietetics are taught. Both authors have had experience teaching this information in advanced nutrition courses and the materials included come from years of experience. We expect this course to provide students with the necessary skills and background to pursue higher-level nutrition classes; it can also serve as a capstone class. As we stated in the prefaces of previous editions, we continue to believe that students who use this text will go on to research careers in nutrition, perhaps even making contributions to the field that we will then cover in future editions of this text. There are those who used the *First Edition* of this book and went on to have research careers in nutrition and dietetics, and their findings are reported in this edition. We certainly look forward to and encourage such important works from future students.

Denis M. Medeiros
Robert E. C. Wildman
Acknowledgments

The authors would like to thank the following reviewers for their thoughtful critiques, expert knowledge, and constructive suggestions, which have helped us in improving this edition.

Elizabeth Cuervo, MD
Professor
Florida National University
Miami, FL

Patricia Davidson, DCN, RDN, CDE, LDN, FAND
Assistant Professor
West Chester University
West Chester, PA

Michael A. Dunn, PhD
Associate Professor
University of Hawaii at Manoa
Honolulu, HI

James Gerber, MS, DC
Associate Professor
Western States Chiropractic College
Adjunct Faculty
University of Bridgeport
Bridgeport, CT

Amber Haroldson, PhD, RD
Assistant Professor
Ball State University
Muncie, IN

Jasminka Ilich, PhD, RD
Professor
Florida State University
Tallahassee, FL

Monica Lebre, MS, RDN, LDN
Adjunct Lecturer
Northeastern University
Boston, MA

Dingbo Lin, PhD
Assistant Professor
Oklahoma State University
Stillwater, OK

Pei-Yang Liu, PhD, RD, LD
Assistant Professor
University of Akron
Akron, OH

Mindy Maziarz, PhD, RDN, LD
Assistant Professor
Texas Woman’s University
Houston, TX

Susan Muller, PhD
Professor
Stephens College
Columbia, MO

Nina Roofe, PhD, RDN, LD, FAND
Dietetic Internship Director and Assistant Professor
University of Central Arkansas
Conway, AR

Robert B. Rucker, PhD
Distinguished Professor Emeritus
Department of Nutrition and Department of Internal Medicine
University of California, Davis
Davis, CA
About the Authors

Denis M. Medeiros, PhD, RD, LD, received his PhD in nutrition from Clemson University in 1981, his MS in physiology from Illinois State University in 1976, and his BS degree from Central Connecticut State University in 1974. He has been on the faculties of Mississippi State University (1981–1984), the University of Wyoming (1984–1989), The Ohio State University (1989–2000), and Kansas State University (2000–2011). He is currently Dean Emeritus of the Graduate School and Professor Emeritus of Molecular Biology and Biochemistry at the University of Missouri at Kansas City. Formerly, Dr. Medeiros was full professor and head of the Department of Human Nutrition, as well as associate dean for scholarship and research, at Kansas State University. He holds the rank of Professor Emeritus of Food, Nutrition, Dietetics, and Health and Associate Dean Emeritus for Scholarship and Research at Kansas State University. He was a former associate dean for research and dean of the College of Human Ecology at The Ohio State University. He has also spent time as a visiting faculty member at the Medical University of South Carolina in Charleston, South Carolina, and at the Washington University School of Medicine in St. Louis, Missouri.

Dr. Medeiros’s major research has focused on the role of trace minerals, particularly copper, on the integrity of the cardiovascular system, and on the role of iron in bone integrity. He has received more than $4 million in grants to support his research endeavors from such institutions as the National Institutes of Health, the U.S. Department of Agriculture, and the National Science Foundation. He has authored or coauthored more than 125 scientific peer-reviewed articles. Additionally, he has served on numerous editorial boards of prominent journals and has held elective offices in scientific societies. He has taught classes, both at the introductory and advanced levels, for undergraduate students and has taught graduate-level courses throughout his career. In addition, Dr. Medeiros has received outstanding teaching awards for his efforts and is both a registered and licensed dietitian.

Robert E. C. Wildman, PhD, RD, LD, FISSN, received his PhD in human nutrition from The Ohio State University, his MS in foods and nutrition from The Florida State University, and his BS in dietetics and nutrition from the University of Pittsburgh. He is a fellow of the International Society of Sports Nutrition (ISSN) and is an adjunct faculty member in the Department of Food Science and Human Nutrition at Texas Woman’s University in Denton, Texas. His major areas of research include nutrition application to metabolism, body composition, weight control and health, and athletic performance. He has authored or coauthored more than 30 papers and several nutrition books, including The Nutritionist: Food, Nutrition, and Optimal Health and Sport and Fitness Nutrition; he also edited the Handbook of Nutraceuticals and Functional Foods. Dr. Wildman is a registered and licensed dietitian with the Academy of Nutrition and Dietetics and is the creator of TheNutritionDr.com.