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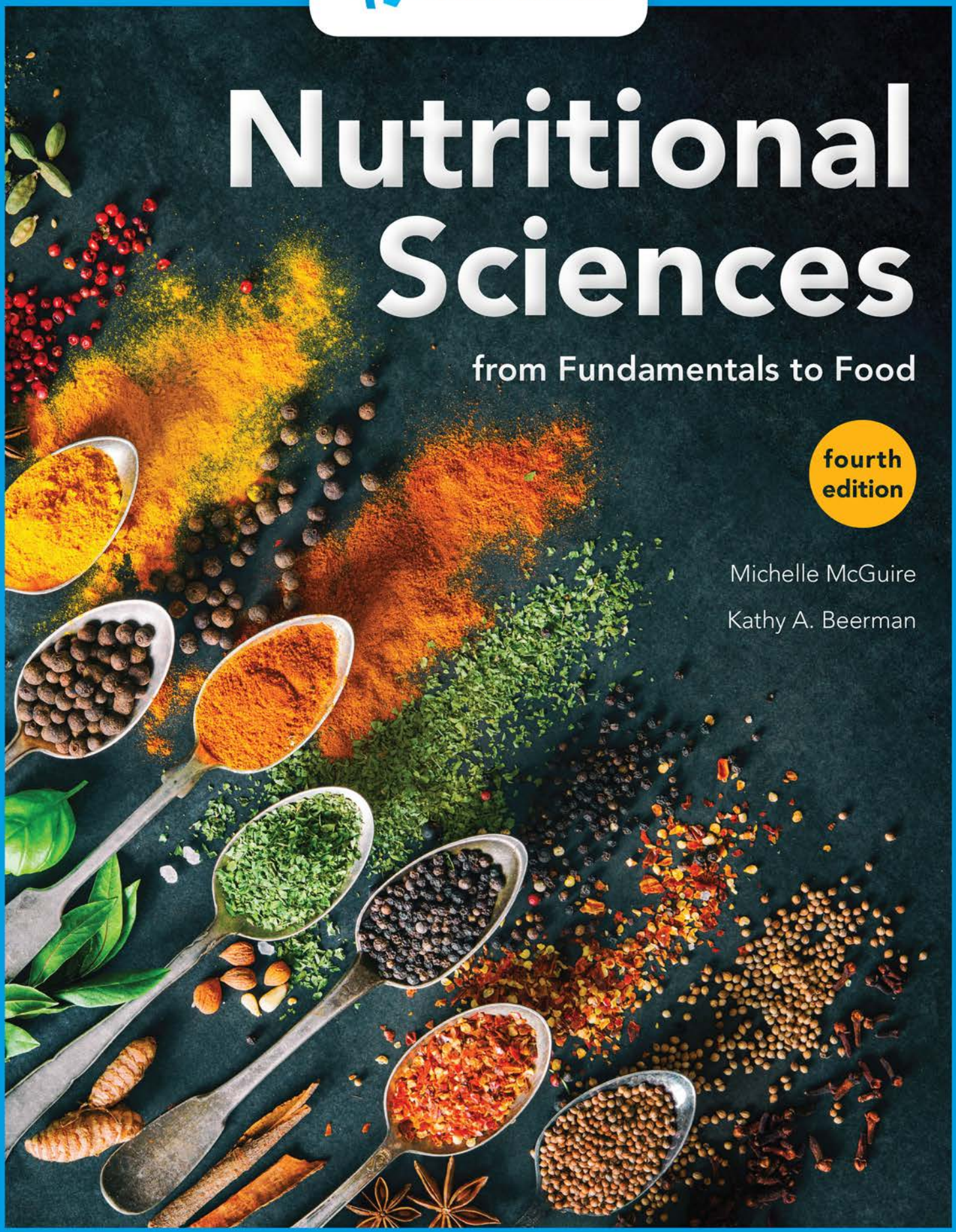
Nutritional Sciences

from Fundamentals to Food

fourth edition

Michelle McGuire

Kathy A. Beerman



Fourth Edition

Nutritional Sciences

From Fundamentals to Food

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CENGAGE

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***Nutritional Sciences*: *From Fundamentals to Food,* Fourth Edition**
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Everybody Has a Story: Michelle "Shelley" McGuire

Courtesy of the University of Idaho

Dr. Michelle "Shelley" McGuire got her academic start in the small town of Polo, Illinois, where her mother-in-law-to-be (a high school English teacher) taught her how to write, and her family and community instilled within her a strong Midwestern work ethic and love of learning. Shelley earned a bachelor's degree in biology from the University of Illinois, a master's degree in nutritional sciences from the University of Illinois, and a doctorate in human nutrition (with minors in physiology and international nutrition) from Cornell University. After serving as a faculty member at Washington State University for over two decades, she is now the Director of the Margaret Ritchie School of Family and Consumer Sciences and Professor of Nutrition at the University of Idaho, where she has the privilege of guiding a wonderful group of like-minded professionals and conducting research related to nutrition, lactation, and maternal/infant health. Recent research, conducted in collaboration with her husband Dr. Mark McGuire and colleagues Dr. Janet Williams and Dr. Courtney Meehan and funded primarily by the National Institutes of Health, the National Science Foundation, and the Bill and Melinda Gates Foundation, has focused on the discovery that human milk naturally contains "healthy" bacteria that likely benefit both mothers and infants. During the worldwide COVID-19 pandemic, Shelley and her colleagues were also instrumental in determining that SARS-CoV-2 is not transferred from mother to infant while breastfeeding. Shelley is an active member of the American Society for Nutrition, for which she has served as National Spokesperson and a member of its Executive Board and of various committees. She is also an active member of the International Society for Research in Human Milk and Lactation, also having served on its Executive Committee. Dr. McGuire taught basic nutrition courses for mixed majors for over 20 years and has a strong appreciation for the course goals and objectives, as well as the wide variety of student needs associated with the course. She has also taught upper-level science communications courses. These experiences, coupled with her strong writing skills, research background, and personal connections within the international nutrition research community, have helped her create an exciting and refreshing text for the introductory nutrition course. When Shelley is not writing, teaching, or overseeing research, she enjoys being with her family and friends, traveling, playing with her Nova Scotia Duck Tolling Retrievers, running, practicing yoga, cooking, gardening, singing, and playing classical music.

With continued and heart-felt gratitude to my family (Mark, Emily/Michael, Grace, and Keith/Michaela) for providing the love, balance, perspective, and support I need to make the difference I want to make in this world.

This revision is dedicated to Kathie and Tina, my loyal, dedicated, and somewhat crazy running partners and friends. I am so grateful that you're both in my life. Here's to many more years of crack-of-dawn runs, enduring advice, and hearty laughter.

Shelley

Everybody Has a Story: Kathy Beerman

I express my deepest gratitude to my family and friends who supported me through the many twists and turns of this endeavor; you have all contributed to this book in many ways. I am especially grateful to my husband, who provided endless and unwavering love each step of the way. My greatest inspiration comes from my father, Morris Beerman, whose profound wisdom has guided me throughout life. It is to him that I dedicate this book.

Kathy

Courtesy of Washington State University

Dr. Kathy Beerman was born and raised in Buffalo, New York. She earned her bachelor's and master's degrees from the State University of New York at Brockport, Department of Health Sciences. Although her urban, East Coast roots run deep, she relocated to Corvallis, Oregon, to attend graduate school at Oregon State University, where she earned her PhD. After finishing her doctorate, Kathy and her husband (Steven) moved to Moscow, Idaho. Now a professor of nutrition, Kathy teaches in the School of Biological Sciences at Washington State University. The author of several published articles, she is interested in research that focuses on the efficacy of a novel approach to treating iron deficiency anemia in rural regions of Guatemala. In addition to teaching an undergraduate nutrition course for health majors, she is co-director of the Hearts in Motion program at Washington State University. The Hearts in Motion program is a faculty-led, 10-day international medical mission to Guatemala that provides health care to those living in extreme poverty. Since joining the faculty at Washington State University in 1990, Kathy has been the recipient of several teaching awards (the Burlington Northern Faculty Meritorious Achievement in Teaching Award, the R.M. Wade Foundation Award for Excellence in Teaching, and the Sahlin Faculty Excellence Award for Instruction). More recently, she received the College of Arts and Sciences Outstanding Achievement Award in International Activities (2017) and the President's Award for Leadership (2018). In addition, Dr. Beerman was inducted into the President's Teaching Academy at Washington State University, which is composed of faculty members who provide leadership to strengthen undergraduate and graduate teaching and learning. In addition to her work at Washington State University, Dr. Beerman writes monthly research media releases for the American Society of Nutrition. Dr. Beerman's years of teaching experience combined with her wide knowledge base in nutrition and health sciences have helped her create this innovative introductory nutrition textbook. At home, Kathy enjoys spending time with her family (Steven, Anna/Gavin, and Michael/Kate) and friends. She is particularly grateful for her running partners and their shared miles of early morning conversations. Besides running, Kathy also enjoys traveling, gardening, and being a part of the Moscow community.

Preface

Like you, we teach introductory nutrition at the college level, and our experiences in the classroom have taught us many things. We would like to share two primary insights that shaped the inception of this textbook and have guided us throughout the writing of each edition.

- First and foremost, an introductory nutrition textbook must explain nutrition concepts accurately, clearly, and completely in a way that all students, regardless of level or background, can understand. To do this most effectively, it is essential to provide students with fundamental scientific concepts. Only then can these concepts be applied to the science of nutrition in a meaningful way.
- For some students, scientific concepts are abstract and difficult to grasp. For this reason, the use of well-designed figures greatly enhances learning by providing integrated, contextually based illustrative examples of biological processes.

These two straightforward observations formed the genesis of this textbook. It is our hope that this book will allow all students, even those with little or no science background, to find the science of nutrition approachable, understandable, and—perhaps most imperative—useful in their lives.

Critically important to the evolution of this textbook is our commitment to getting the facts straight, updating the text as new knowledge unfolds, and presenting information in an objective, unbiased manner. As such, the revision process is an integral part of all stages of textbook development, writing, and implementation. When necessary, subject matter experts are consulted to clarify concepts, discuss implications of a new study, provide commentary on new scientific discoveries, or even help us define terms. If you are one of these people we have reached out to, thank you! We also attend national meetings, participate in conferences, and seek out nutrition-related events to ensure that we are on the cutting edge of the science. In addition, and perhaps most importantly, we use this textbook in our classrooms and solicit feedback from our students. Sometimes we learn as much from them as they learn from us.

All these approaches made us even more eager to roll up our sleeves and dive into this new edition. If you used previous editions of this book, you would immediately notice that many changes have been made to every chapter. These changes are described in more detail later in this preface. Although we are confident that this book is one of the most accurate, clearly written, current, beautiful, and student-friendly nutrition books available, we will have already started working on the next edition by the time you are reading this page. Please do not hesitate to let us know whether these changes address your needs and those of your students, as well as what you would like us to address in subsequent editions.

The Fundamentals Are Important

We think you will agree that students need a strong knowledge base to master nutrition concepts. Without knowledge of fundamental scientific principles and associated vocabulary, many capable students in introductory nutrition

courses are lost from the start. For example, when teaching nutrition, we often refer to chemical bonds—how else do we distinguish between saturated and unsaturated fatty acids? Similarly, when teaching the importance of ATP, we discuss the breaking of phosphate bonds. But how can a student grasp these concepts without understanding what a chemical bond is? The solid scientific foundation provided by this book will enable students to navigate through the most difficult of concepts, regardless of their background. For example, Chapter 3 not only introduces the basic principles of chemistry, biology, and physiology, but also applies these concepts to the study of nutrition. To our knowledge, this is the first introductory nutrition textbook to present such a "primer" on nutritional biochemistry and physiology at the level appropriate for both science and nonscience students. In fact, because we believe that the fundamentals are so crucially important, we worked hard to define and describe each new science-based term and concept when it is introduced. You will see evidence of this in every chapter.

An Integrated, Yet Systematic, Approach

As the field of nutrition grows, so does the amount of information we must teach. Consequently, it can be difficult to cover the necessary basic science and applied aspects of nutrition in a single semester. For instance, it is important to first learn about all of the related macronutrients and micronutrients before launching into a full discussion of nutrition and health. Therefore, our approach has been to "lead" with the basics, followed by application whenever possible. To accomplish this, we have organized the text in a methodical, integrated manner. First, the main chapters of the book are organized in the traditional way—starting with the macronutrients and then discussing the micronutrients. However, applied concepts are integrated throughout the book. For example, active and passive transport mechanisms are carefully described in Chapter 3, but then referred to in subsequent chapters throughout the book. Another pedagogical tool, called **Connections,** is conveniently placed on pages to provide students with a quick reminder of important terms and concepts. Similarly, a structural organization of headings and subheadings provides students with a framework that presents a broad view, which then progresses to a more detailed examination of information. By posing first-level headings as questions, students can self-check to ensure they are extracting critical information.

Second, we have continued to use a feature entitled **Focus on…,** which highlights issues related to scientific innovation, diet and health, food, clinical applications, life cycle nutrition, and sports nutrition. These features assimilate topics that are of great interest to students within appropriate chapters and are especially useful to instructors who do not have time to cover them more extensively during the semester. For example, a Focus on Science discusses the gastrointestinal tract microbiome, which accompanies the section on body weight regulation, and a Focus on Clinical Applications provides an illustrative discussion regarding nutrient–drug interactions, which accompanies the section on vitamin K. Most chapters have several Focus on… features, which students will enjoy reading and from which they will learn a great deal. In fact, these features received high praise from our students, who found the topics interesting and provocative.

Third, to improve the integration of important nutrients related to the maintenance of health or the risk for chronic disease, we include segments called **Nutrition Matters,** which conclude most of the chapters. These "minichapters"

deal with important nutrition-related issues—such as diabetes, nutrition and cancer, food safety, and food security. They are up-to-date and comprehensive, yet clear and student friendly. Because these pieces conclude most chapters, instructors can easily choose to assign them in any order that works for their class, or not assign them at all if time does not allow.

Putting a Personal Face on Nutritional Science

We all know that stories are memorable and can greatly enhance learning. Without a doubt, teachers double as storytellers. If you are like us, your "stories" are often about people with nutrition-related challenges in their lives. And you would probably agree that everybody has such a story to tell. A special feature called **Everybody Has a Story** made its first debut in the second edition of the textbook. As in the second edition, each chapter opens with a story about a person with a real nutrition-related challenge. In this new edition, we are pleased to introduce several new people, all of whom generously shared their captivating stories. It is our hope that students can relate to these stories and refer back to them as they read the chapter. For example, Chapter 2 (Nutritional Assessment and Dietary Planning) features Emily, a student studying at the University of Cincinnati. This story was selected to get students to think about how easily overlooked medical conditions—such as celiac disease—can cascade into a host of nutrient-related concerns, especially in college students facing a multitude of changes and stresses in their lives. Chapter 8 (Energy Balance and Body Weight Regulation) features Roberto, who describes the life circumstances that contributed to his weight gain. Roberto's struggle with obesity led to his decision to have surgery after repeated failed weight-loss attempts. This story presents a thought-provoking perspective to students about the physical, psychological, and sociocultural aspects of obesity. Most importantly, it challenges students to examine their beliefs about this sensitive topic. We are hopeful that these personal stories will help students connect the fundamentals of nutritional science to everyday living and health.

This book also provides numerous opportunities for students to apply their knowledge to the art and science of making their own healthy food choices on a daily basis. The **Food Matters** sections, for example, help transform the 2020–2025 Dietary Guidelines for Americans (which are described in detail in Chapter 2) into practical ideas for choosing and preparing foods in the most health-conscious manner. These pieces can be found in most chapters, helping integrate the fundamental concepts into personal food-related decisions.

Book Length

Most introductory nutrition courses are taught over one quarter or semester. Yet textbooks written for these courses typically contain substantially more information than can be covered within a 10- to 15-week period. Addressing concepts in a concise manner has enabled us to create a slimmer, trimmer textbook that can be more easily covered in a single semester. Additional resources that might otherwise be found in an appendix are conveniently provided to students via the book's website or can be bundled as supplements to the textbook.

Pedagogical Tools

As previously described, we are convinced that outstanding illustrations enhance learning. All students benefit from seeing scientific concepts articulated in clear, well-organized illustrations. The figures, tables, and graphs in this book were designed using a unique captioning system, and the consistent use of blue text boxes and lines quickly identifies the key points of each figure. Many of our visual summaries take students step by step through complex processes, from the whole-body "big picture" to specific, focused details. We affectionately refer to these as "you are here" illustrations and have noticed other textbook writers adopting this idea and using it in their books as well.

Additionally, and to help with recognition, extra effort has been made to ensure that components found in many figures are displayed consistently throughout the book. For example, the anatomical drawings are rendered in the same way so that various organs such as the liver, pancreas, and stomach have a consistent appearance; glucose is always colored blue; and phospholipids are always drawn and colored the same way.

In addition to beautiful illustrations, each chapter contains a number of helpful tools that assist students in learning the material.

New to the Fourth Edition

Perhaps most exciting to us are the many subtle and not-so-subtle changes we have made to transform this book into its fourth edition. Many of these changes were made in response to excellent feedback that we received from both colleagues and students, and we thank you all for helping us make this edition even better. First, you can look forward to reading new challenges in the **Everybody Has a Story** features, and we welcome your feedback on how these helped in the classroom. In addition, we have added targeted learning outcomes to each chapter.

And, of course, throughout the book we have updated all the nutrition-related guidelines and programs discussed, as well as health statistics. Importantly, this edition has been updated to include the 2020–2025 Dietary Guidelines for Americans and the MyPlate food guidance system. Another of the most important considerations during the revision process was to avoid layering new material on top of old. Therefore, sections that no longer seemed relevant or supported by the literature were removed.

It is noteworthy that we have devoted substantial thought and effort to make the fourth edition of our textbook as inclusionary as possible. To that end, we have worked to be inclusive to all ages, genders, ethnicities, and identities. We strengthened the text by using a more direct, gender-neutral, panoptic voice. This attention to diversity and inclusion reflects our deep conviction that understanding nutrition is relevant to every human. We hope this style will resonate with students and help them grasp important concepts more readily.

This edition of our textbook was written during the worldwide COVID-19 pandemic, and as much as possible we included references to how this event (which was still ongoing as the book went to press) impacted the nutrition and health of the nation and the world. For instance, at the beginning of the pandemic there was substantial concern as to whether SARS-CoV-2 could be transmitted via foodborne illness. We took the opportunity to address this and other food- and nutrition-related issues associate with the pandemic as appropriate.

Perhaps most important to any rigorous college-level textbook, each chapter now includes new information that reflects changes to our knowledge that

have surfaced since the last edition was released. Some of these are highlighted here.

Chapter 1 (The Science of Nutrition)

- Expanded discussion regarding experimental design to include concepts of "dependent variable" and "confounding variable."
- Defined "comorbidity" when discussing life expectancy and included COVID-19 in list of infectious diseases important to Americans.

Chapter 2 (Nutritional Assessment and Dietary Planning)

- Updated discussion of DRIs to reflect the reorganization of the National Academy of Sciences and the addition of a new category for Chronic Disease Risk Reduction Intakes (CDRRs).
- Updated U.S. Dietary Guidelines for Americans recommendations to the 2020 version. Specifically discussed the new lifespan approach and inclusion of recommendations for infants younger than 2 years of age.
- Replaced information regarding Healthy People 2020 with that contained in Healthy People 2030.
- Updated Nutrition Facts panels to reflect new look and required information.

Chapter 3 (Chemical, Biological, and Physiological Aspects of Nutrition)

- While this chapter continues to provide a strong foundation in physiological functions, we have provided more examples that demonstrate their applicability to the study of nutrition.
- A new Everybody Has a Story chapter opener features Jeska, who struggled for years with an unspecified illness. Eventually diagnosed as gastroparesis, her struggle with impaired digestion is woven throughout this chapter.
- A new section fully explores the physiology of taste and smell. Figures illustrating these processes have also been added. Taste and smell are discussed further in a feature that relates the loss of taste because of certain diseases such as COVID-19.
- A new "Focus on" feature regarding the role of the microbiome in health and disease has been added. A new "Focus on" feature regarding the causes of impaired taste and smell and its impact on food intake has been added.
- Core concepts related to digestion and nutrient absorption have been updated, and new information has been added throughout the chapter.

Chapter 4 (Carbohydrates; Nutrition and Diabetes)

- A new Everybody Has a Story chapter opener features Teddy, a teenager diagnosed with Type 1 diabetes. Teddy's story highlights the importance of blood glucose regulation.
- A new "Focus on" feature explores the relationship between high fructose intake and nonalcoholic fatty liver disease.
- A new "Focus on" feature explores the evolution of lactose tolerance.
- Updated information regarding the role of oligosaccharides in human milk.
- Updated information based on the 2020 Dietary Guidelines for Americans regarding added sugar consumption in the United States.
- Updated information based on the 2020 Dietary Guidelines for Americans regarding emphasis on fiber, fruit, and vegetable intake.
- Updated Centers for Disease Control and Prevention (CDC) trend maps showing recent regional estimates of adults with diagnosed diabetes.
- Incorporated the 2020 Dietary Guidelines for Americans and MyPlate food guidance system where appropriate.

- Included American Diabetes Association's 2020 guidelines for carbohydrate intake.
- Updated information regarding advances in glucose monitoring technologies such as insulin pumps and continuous glucose monitoring devices. The rising cost of insulin is also addressed.

Chapter 5 (Protein; Food Safety)

- Revised protein food intake recommendations based on the 2020 Dietary Guidelines for Americans and MyPlate food guidance system.
- Updated "Focus on" feature about sickle cell anemia to include discussion on new treatments.
- Updated discussion regarding consumption of red meat and cancer based on the 2015 report by the International Agency for Research on Cancer.
- Updated examples of recent foodborne illness outbreaks in the U.S.
- Added a section describing the FDA's designation as "generally recognized as safe" (GRAS).
- Removed discussion of acrylamide and added discussions regarding perfluorooctane sulfonate (PFOS), heavy metals in baby foods, and COVID-19.
- Added section regarding ultra-high temperature processing (UHT).

Chapter 6 (Lipids; Nutrition and Cardiovascular Health)

- Revised food intake recommendations based on the 2020 Dietary Guidelines for Americans and MyPlate food guidance system.
- Replaced "Focus on" feature related to fat substitutes with one describing shifting lipid recommendations over time.
- Added new "Focus on" feature discussing global goals to decrease consumption of *trans* fatty acids.

Chapter 7 (Energy Metabolism; Alcohol, Health, and Disease)

- Included new Everybody Has a Story chapter opener describing the importance of newborn genetic screening and how diet plays an important role in managing PKU, an inherited metabolic disease.
- Revised figures illustrating the processes of enzymatic catalysis, beta-oxidation, amino acid metabolism, and the impact of feeding and fasting on energy metabolism. are included in this new edition.
- Updated information concerning the use of therapeutic ketogenic diets to help control seizures in some children.
- Added a "You are here" illustration to provide students with an integrative view of the various pathways involved in energy metabolism.
- Added application of basic concepts of energy metabolism to topics such as alcohol metabolism, inherited metabolic disorders, and sports nutrition.
- Updated information on alcohol consumption on college campuses and revised guidelines for responsible alcohol use.

Chapter 8 (Energy Balance and Body Weight Regulation; Disordered Eating)

- Included new Everybody Has a Story chapter opener that explores life circumstances that can contribute to obesity and the decision to have weight reduction surgery.
- Updated information and statistics regarding U.S. obesity trends.
- Expanded discussion pertaining to food cravings, food aversions, and food addiction.
- Updated information regarding the gastrointestinal tract microbiome and new research that explores a plausible relationship with body weight regulation.

- Inclusion of a new model for understanding weight gain and weight loss called the dual intervention point.
- Addition of new information regarding intermittent fasting and continuous energy restriction.
- Included overview of the National Association for Sports and Physical Education guidelines for physical education in schools.
- Expanded presentation of the 2018 Physical Activity Guidelines for Americans.
- Updated information regarding obesity, inflammation, and chronic disease.
- Included new, updated tables summarizing feelings and behaviors associated with anorexia nervosa and bulimia nervosa.
- Expanded discussion of other dysfunctional eating patterns such as food neophobia, muscle dysmorphia, and night eating syndrome.
- Included prevalence of eating disorders among underrepresented groups such as Black, Indigenous, and people of color, lesbian, gay, bisexual, transgender, and queer individuals, as well as people with disabilities who struggle with eating disorders.

Chapter 9 (Physical Activity and Health)

- Expanded text related to the 2018 Physical Activity Guidelines for Americans and recommendations by the American College of Sports Medicine.
- Expanded and updated discussion of nutritional guidelines for athletes.

Chapter 10 (Water-Soluble Vitamins, Choline, and Carnitine)

- Added new "Focus on" feature related to the complex association among B vitamins, the GI microbiome, and health and included specific information for individual B vitamins as appropriate throughout the chapter.
- Updated information related to fortification of food, based on U.S. FDA guidelines.
- Included new information about genetic polymorphisms related to risk of vitamin deficiencies.
- Updated statistics related to neural tube defects in the U.S.
- Revised intake recommendations for water-soluble, vitamin-rich foods and choline based on the 2020 Dietary Guidelines for Americans and MyPlate food guidance system.
- Added section describing Supplement Facts panels.

Chapter 11 (Fat-Soluble Vitamins; Nutrition and Cancer)

- Revised section regarding calcium homeostasis to more clearly delineate the involvement of the small intestine and bone.
- Revised intake recommendations for fat-soluble vitamin-rich foods based on the 2020 Dietary Guidelines for Americans and MyPlate food guidance system.
- Removed section on vitamin D deficiency and Alzheimer's Disease to reflect current literature.
- Updated statistics related to cancer morbidity and mortality.
- Added discussion of cancer cachexia and other nutrition-related outcomes caused by cancer or its treatment.
- Expanded discussion related to racial and ethnic disparities in cancer incidence.
- Added section regarding use of e-cigarettes and cancer risk.
- Updated dietary recommendations by the American Institute of Cancer Research and the World Cancer Research Fund to help decrease risk of cancer.

Chapter 12 (Major Minerals and Water; Nutrition and Bone Health)

- Updated information concerning recommended intakes of sodium and chloride based on new Chronic Disease Risk Reduction Intake values.
- Added "hypocalcemia" and "hypercalcemia" to vocabulary.
- Revised intake recommendations for major mineral-rich foods based on the 2020 Dietary Guidelines for Americans and MyPlate food guidance system.
- Included information regarding sources of sodium in the U.S. diet.
- Added new discussion of blood pressure measurements, including reference to systolic and diastolic values.
- Updated statistics related to osteoporosis morbidity, morality, and associated costs.

Chapter 13 (Trace Minerals)

- Revised section on iron absorption to include ferroportin and better reflect current knowledge.
- Updated statistics related to hereditary hemochromatosis.
- Added new Focus on section describing emerging ways to increase iron consumption in the developing world.
- Included discussion of Wilson's disease.
- Added new section related to iodine deficiency during pregnancy and lactation.
- Updated dietary intake recommendations related to mineral-rich whole-grain products based on the 2020 Dietary Guidelines for Americans and MyPlate food guidance system.

Chapter 14 (Life Cycle Nutrition; Food Security, Hunger, and Malnutrition)

- Included new Everybody Has a Story chapter opener that tells the story of an adopted infant born with a cleft palate and cleft lip. This feature is revisited throughout the chapter and addresses the feeding challenges associated with infancy, childhood, and adolescence.
- Added new research on screen time and the rising concern of childhood obesity.
- New emphasis on responsive feeding practices that help parents understand cues of hunger and satiety in children.
- Added new "Focus on" feature discusses the human milk microbiome.
- Included new "Focus on" feature presents cutting edge research regarding the importance of antioxidants and eye health in older adults.
- Included new New USDA terminology related to ranges of food security and food insecurity.
- Updated trends regarding food insecurity in the United States.
- Discussed impact of COVID-19 on food insecurity in the United States.
- Introduced several important contemporary concepts such as low-income and low-access food areas.
- Expanded discussion addressing food insecurity in the United States and community resources such as community food councils, farmers markets, farm to school networks, produce prescription programs, and American's Healthy Food Financing Initiative.
- Updated information and statistics reflecting national and international food security and hunger.
- Expanded discussion on the impact of political unrest and urbanization on worldwide hunger and malnutrition.
- Added new information on the impact of climatic events on food production.
- Expanded coverage of global efforts to alleviate food insecurity and malnutrition.

Supplements

- **MindTap Nutrition:** MindTap for McGuire/Beerman, Nutritional Sciences: From Fundamentals to Food, 4e, todays' most innovative online learning platform, powers your students from memorization to mastery. MindTap gives you complete control of your course to provide engaging content, challenge every individual, and build student's confidence.
- **Instructor Companion Site:** Everything you need for your course in one place! This collection of product-specific lecture and class tools is available online via www.cengage.com/login. Access and download PowerPoint presentations, images, instructor's manual, and more.
- **Test Bank with Cognero:** Cengage Testing, powered by Cognero® is a flexible, online system that allows you to import, edit, and manipulate content from the text's test bank or elsewhere, including your own favorite test questions; create multiple test versions in an instance; and deliver tests from your LMS, your classroom, or wherever you want.
- **Diet & Wellness Plus:** Diet & Wellness Plus helps you understand how nutrition relates to your personal health goals. Track your diet and activity, generate reports, and analyze the nutritional value of the food you eat. Diet & Wellness Plus includes over 75,000 foods as well as custom food and recipe features. Diet & Wellness Plus is also available as an app that can be accessed from the app dock in Mindtap.

Acknowledgments

Revising a textbook is much like the process of spring cleaning. That is, to stay fresh, organized, and reinvigorated one must be insightful about what has proven worthy, and what can be discarded. Only when these decisions have been made and the "closet emptied" is there room for new elements to be woven into the existing tapestry of the book's pages. That is exactly what we tried to do in the fourth edition of this book, and we certainly could not have done it alone. We are indeed fortunate to have teamed up with the experienced and skillful professionals at Cengage Learning. Their guidance was invaluable, enabling us to transform our evolving vision into this quality textbook. We will forever be grateful for their encouragement and continued support throughout this entire process. Our special thanks are extended to Sean Campbell and Ann Borman who expertly, professionally, and graciously led us through the complicated process of a textbook revision.

We are also thankful for the many expert reviewers who took the time to read each chapter and provide invaluable feedback in terms of content and clarity. We certainly could not have produced an up-to-date textbook without this critical input. And we would like to extend a heartfelt thank you to those who allowed us to share their interesting life stories with the readers of this textbook. These stories, as featured in the new Everybody Has a Story pieces, would not be possible without these people's willingness to discuss the daily challenges they face. We all have a great deal to learn from their experiences and triumphs. Last, to all our friends, families, and colleagues who helped in more ways than they will ever know: Thank you for being fellow travelers on this ever-important journey.

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Fourth Edition

Nutritional Sciences

From Fundamentals to Food

Chapter

1 The Science of Nutrition

Learning Objectives

1-1 Define nutrition as a science and as a field for both work and study.

1-2 Outline the role of nutrients in the body and explain what determines if they are considered essential, nonessential, or conditionally essential.

1-3 List the six classes of nutrients and differentiate between their key properties and classifications.

1-4 Explain how nutrients in food provide energy to the body and calculate the calories and percentage of calories in a food.

1-5 Outline the scientific method and key factors to consider in the design of research studies.

1-6 Compare and contrast the different types of studies used in nutrition.

1-7 Distinguish between reliable science-based nutrition information and misinformation and how to identify credible, evidence-based sources for information.

1-8 Summarize the role that nutrition plays in health, longevity, and disease and how this has changed over time.

Let thy food be thy medicine and thy medicine be thy food.

—Hippocrates (460–364 B.C.)

Life would not be possible without the nourishment of food. Indeed, our quality of life depends greatly on which foods we choose to eat, and experts unanimously agree that the foods we eat can greatly influence both our immediate health and our risk of disease as we age. Hopefully, you are reading this textbook because you are majoring in nutrition or simply interested in learning how the nutrients in what you eat impact your health. Either way, the information you learn in this course is knowledge you can apply throughout the rest of your life.

Perhaps the first few questions you ought to ask yourself as you embark upon this journey of learning are *"Do I choose my foods wisely?"* and *"What changes should I make to ensure optimal nutrition and a long and healthy life?"* To answer

Everybody Has a Story

Choosing Nutrition as a Career Path

Yimin has always enjoyed good food and the pleasures of eating, but she never imagined she would pursue a career in nutrition. However, she realizes that she has long understood the importance of a healthy diet for both physical and mental health when she recalls her experiences as an overweight child competing at the local swimming club. Science was not one of Yimin's passions as she went through her high school years. Instead, she was much more interested in music and tennis, and Yimin was emphatic that she would do nothing related to science, partly because she found her high school science laboratories "contrived and not useful to her daily experience." Instead, she entered the University of Idaho as an elementary education major and planned to pursue a career as a teacher in the public schools.

To fulfill her general education requirement in biology, Yimin enrolled in an introductory microbiology class during her first year of studies. She wasn't really interested in the class but took it because her friends reassured her that the professor was engaging and fair. Much to her surprise, Yimin rapidly learned that college-level science was very different from what she had experienced in high school. She understood, for the first time, that many scientific disciplines were incredibly applicable to her own life as well as the health and well-being of society. She found the section on foodborne illness in the course particularly interesting because it emphasized how a person's dietary choices can immediately and profoundly impact one's health.

After a few months, Yimin switched her major to dietetics and began working in a nutrition research laboratory on campus. She found the science of nutrition not only compelling, challenging, and useful, but that she also thoroughly enjoyed the basic work required to carry out nutrition experiments and analyze their results. Yimin is now a graduate student working on her doctorate in nutrition at the University of Illinois. Her graduate research focuses on how consumption of probiotic foods impacts the immune system during aging, and she has presented her work at national and international conferences.

For Yimin, the realization that she wanted to make science—specifically, nutritional science—her career calling came somewhat late in her undergraduate career and as a complete surprise. Indeed, keeping one's options open during college and exploring various disciplines of study are some of the most important tasks of any college student. Sometimes one class can change your life. Is it possible that the introductory nutrition class you are now enrolled in might have this impact on your life? ■

Nicola Tree/Stone/Getty Images

Critical Thinking: Yimin's Story

Why are you taking this nutrition class, and what are your personal goals for what you will learn? Are there specific issues that are of special interest to you as you embark upon your study of nutrition? Why are you especially interested in these topics? Has nutrition been an interest of yours for many years, or has some situation or experience made you particularly interested in learning more about it?

these questions, you must first understand what nutrients are and how your body uses them to maintain and fuel all its complex physiologic processes. In other words, it is important that you understand the science of nutrition.

Science is powerful. It helps explain our world, makes it a better place to live, and contributes to good health. Yet scientific progress almost always generates considerable debate. Not surprisingly, nutritional discoveries that have helped prevent and cure diseases are often met with both excitement and skepticism. One day you may read in a newspaper, "Vitamin A decreases risk of heart disease." Later, you read the headline, "Vitamin A increases risk for cancer." Likewise, an article that says, "You should eat more fish" may be followed by one that asserts, "Fish contains dangerous heavy metals." While it offers great hope for improving health, nutritional science also generates controversy.

There is no argument, however, that nutrition and its impact on human health are of crucial importance. Nutritional deficiencies have always posed major health challenges worldwide, but today nutritional abundance and imbalance also contribute to many of our health problems. Poor dietary choices you make now may play a major role in predisposing you to obesity, cancer, heart disease, osteoporosis, and type 2 diabetes later in life. This chapter discusses the fundamental concepts necessary to understand how good nutrition is basic to your health. You will also learn how scientists study nutrition. With this knowledge, you will be able to make sound decisions about selecting a healthy diet based on scientific reason, not rumor, for years to come.

1-1 What Do We Mean by "Nutrition"?

Perhaps the first question you may have is what the term *nutrition* actually means. The term **nutrition** refers to the science of how living organisms obtain and use food to support all the processes required for their existence, and the study of nutrition incorporates a wide variety of scientific disciplines. Some nutritionists are interested in food production and availability, whereas others are interested in studying factors that influence food choice. Still others investigate the relationships between diet and heart disease, how nutrition can influence athletic performance, or how the composition of meals may influence weight management. Indeed, the field of nutrition encompasses a broad array of important scientific and cultural aspects.

Scientists who study nutrition are called **nutritional scientists** and can be found in many disciplines, including immunology, medicine, genetics, biology, physiology, biochemistry, education, psychology, and sociology, as well as nutrition. **Dietitians** are nutrition professionals who help people make dietary changes and food choices to support a healthy lifestyle. Dietitians have the credentials of "RD" or "RDN," which stand for *r*egistered *d*ietitian or *r*egistered *d*ietitian *n*utritionist, respectively. Many dietitians are also involved in research. Thus, the science of nutrition, collectively called the **nutritional sciences,** reflects a broad spectrum of academic and social disciplines.

nutrition The science of how living organisms obtain and use food to support processes required for life.

nutritional scientists A person who conducts and/or evaluates nutrition-related research.

dietitian A nutritionist who helps people make healthy dietary choices.

nutritional science A broad spectrum of academic and social disciplines related to nutrition.

nutrient A substance in foods used by the body for energy, maintenance of body structures, or regulation of chemical processes.

Nutrients Support All We Do

But what are nutrients, and why do we need them? **Nutrients** have traditionally been defined as substances in foods required or used by the body for at least one of the following: energy, structure, or regulation of chemical reactions.

Radius Images/Corbis

The dietary choices you make today can influence your health for years to come.

For example, carbohydrates supply energy to fuel your body's activities, calcium and phosphorus are important building blocks for teeth and bones, and many of the vitamins are needed for chemical reactions such as those needed to protect your cells from the damaging effects of excessive sunlight and pollution. There are also many other bioactive substances present in food that appear to have health benefits such as decreasing risks for cancer and heart disease. Scores of these compounds have only recently been discovered and are therefore less understood than the "traditional" nutrients. Clearly, the definition of what is a nutrient is evolving, and the list of established nutrients will likely expand as researchers learn more about how the thousands of substances found in foods can promote health and well-being.

Foods Contain Nutrients and Nonnutrients

You may be surprised to learn that not all compounds in food are nutrients. To convince yourself of this, you need only examine almost any food label. Many compounds found in foods, such as artificial colors, are not nutrients because they do not support basic functions in your body. Scientists classify nutrients into six categories based on their chemical structure and physical properties: carbohydrates, proteins, lipids, water, minerals, and vitamins. Scientists also categorize nutrients and foods in other ways, and some of these classifications are described next.

Essential, Nonessential, and Conditionally Essential Nutrients Although our bodies can use all the nutrients in foods, we only need to consume some of them. These nutrients are referred to as the **essential nutrients.** Essential nutrients must be obtained from your diet because the body requires them and cannot either make them at all or make them in adequate amounts. **Nonessential nutrients** are also required by the body, but your body can make them in amounts needed to satisfy its physiological requirements. Hence you do not actually need to consume nonessential nutrients. Most foods contain a mixture of essential and nonessential nutrients. For example, milk contains a variety of essential vitamins and minerals (such as vitamin A and calcium, respectively) as well as nonessential nutrients (such as cholesterol).

There are situations when a normally nonessential nutrient can become essential. During these times, the nutrient is called a **conditionally essential nutrient.** For example, older children and adults must obtain two essential lipids through the diet, whereas babies are thought to require at least four, which they are unable to make until they get older. The additional lipids are therefore "conditionally essential" during infancy. Certain diseases may also cause normally nonessential nutrients to become conditionally essential. You will learn about some of these in later chapters.

Macronutrients versus Micronutrients Nutrients can also be classified on the basis of how much of them we require from our diet. (Figure 1.1). Water, carbohydrates, proteins, and lipids are called **macronutrients** because they are needed in large quantities (more than a gram each day). Vitamins and minerals are called **micronutrients** because we need only very small amounts of them (often micrograms or milligrams each day). For example, a typical adult requires about 2,726 pounds (1,239 kilograms) of the macronutrient protein over the course of a lifetime but only about 0.3 pounds (0.14 kilograms) of the micronutrient iron.

essential nutrient A substance that must be obtained from the diet, because the body needs it and cannot make it in required amounts.

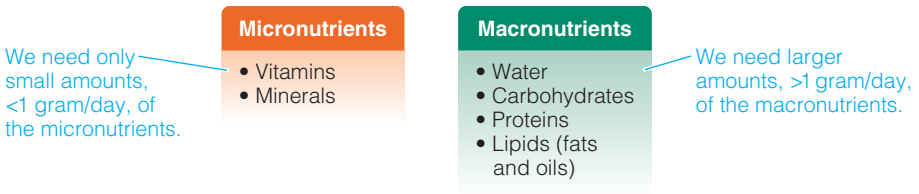
nonessential nutrient A substance found in food and used by the body to promote health but not required to be consumed in the diet.

conditionally essential nutrient Normally nonessential nutrient that, under certain circumstances, becomes essential.

macronutrients Nutrients that we need to consume in relatively large quantities (>1 gram/day).

micronutrients Nutrients that we need to consume in relatively small quantities (<1 gram/day).

Figure 1.1 Micronutrients versus Macronutrients Vitamins and minerals are micronutrients, whereas water, carbohydrates, proteins, and lipids are macronutrients.



Organic Nutrients Are Different From Organic Foods

We can also classify nutrients as being organic or inorganic. By definition, molecules that contain carbon atoms bonded to hydrogen atoms or other carbon atoms are called **organic compounds.** This means that carbohydrates, proteins, lipids, and vitamins are chemically organic nutrients. Water and minerals are **inorganic** because they do not contain carbon–carbon or carbon–hydrogen bonds. Because all foods contain carbohydrates, lipids, protein, or water, they are considered organic—at least in the chemical sense of the term.

The term *organic* also has an additional and very different meaning when it is used to describe how a food (plant or animal) is grown and harvested. A food that is labeled "**Certified Organic**" has been grown and processed according to U.S. Department of Agriculture (USDA) national organic standards. Per these standards, a farmer growing organic crops cannot use many of the pesticides used by conventional farmers. However, farmers do have the option to use certain synthetic and natural pesticides permitted in the USDA's organic guidelines. You can find out what percentage of organic ingredients a product has by reading its food label (Figure 1.2) and learn more about organic foods in the Focus on Food feature.

"Certified organic" foods can be identified by this seal.

Phytochemicals, Zoonutrients, and Functional Foods

As scientists learn more about the relationship between diet and health, they are discovering that, in addition to the traditional or established macronutrients and micronutrients, foods also contain other bioactive substances that influence our health. When health-promoting compounds such as these are found in plants, they are called phytochemicals. They are called zoonutrients when found in animal foods. Although phytochemicals and zoonutrients are not technically considered to be nutrients, research suggests that many are beneficial to health. Some of them may be reclassified as nutrients in the future as scientists learn more about these compounds.

organic compound A substance that contains carbon–carbon bonds or carbon–hydrogen bonds.

inorganic compound A substance that does not contain carbon–carbon bonds or carbon–hydrogen bonds.

certified organic foods Plant and animal foods that have been grown, harvested, and processed without conventional pesticides, fertilizers, growth promoters, bioengineering, or ionizing radiation.

Figure 1.2 Understanding Food Labels of Organic Products

Must have 95–100% certified organic ingredients.

Must have at least 70% certified organic ingredients.

Organic ingredients can be listed on side panel.

No organic claim is being made.

Focus On Food
Understanding What Is Meant by "Organic Foods"

A chemist understands the term organic to generally mean a carbon-containing compound. However, the food industry uses the term *organic* to mean something quite different. In 1992, the U.S. federal government established the National Organic Standards Board (NOSB) to help develop standards for substances to be used (or not used) in organic food production. To learn more about these standards, you can visit the USDA's National Organic Program website at https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program. The NOSB developed the following definition: *"organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity . . . based on management practices that restore, maintain, and enhance ecological harmony."* As such, an organic food must be produced, grown, and harvested without the use of most conventional pesticides, fertilizers made with synthetic ingredients, bioengineering, or ionizing radiation. Furthermore, organic meat, eggs, and dairy products must come from livestock raised without the use of growth-promoting hormones and antibiotics.

Foods with the USDA organic seal labeled as being "100% organic" must have at least 95% organically produced ingredients. Foods labeled as being "organic" must have at least 70% organic ingredients. Products with less than 70% organic ingredients may list specific organically produced ingredients on the side panel of the package but may not make any organic claims on the front of the package (see Figure 1.2).

The USDA makes no claims that organically produced food is safer or more nutritious than conventionally produced food, and the labeling of foods as "organic" is not meant to suggest enhanced nutritional quality or food safety. In fact, there is mixed evidence that organic foods are nutritionally superior to conventional foods.[1] Rather, the difference between organic foods and conventionally produced foods largely involves the methods used to grow, handle, and process them. Whether these alternative agricultural practices promote enhanced environmental integrity and balance is an area of active debate.

Phytochemicals: Beneficial Substances from Plant Foods Although they are not technically nutrients, **phytochemicals** (also called phytonutrients) are substances found in plants that may help reduce the risk for developing certain diseases.[2] In fact, many "health claims" on food packaging labels refer not to traditional nutrients but instead to phytochemicals. For example, consuming phytochemicals found in tomatoes and garlic may decrease your risk of cancer. Grapes and wine contain phytochemicals that may reduce the risk of heart disease. Some phytochemicals function as antioxidants, which protect your body from the damaging effects of toxic compounds such as those found in air pollution. You will learn more about these and other phytochemicals throughout this book.

Zoonutrients: Beneficial Substances from Animal Foods Similar to phytochemicals found in plants, **zoonutrients** (also called zoochemicals) are compounds present in animal-based foods that provide health benefits beyond the provision of traditional nutrients and energy.[3] Examples of zoonutrients include a variety of nonessential lipids found in fish and dairy products that are thought to decrease your risk for heart disease. Another example of a zoonutrient is found in the larval jelly produced by honeybees. This substance has antimicrobial properties and may reduce the risk of infection, although additional research is needed to confirm this.[4]

Functional Foods May Offer Important Health Benefits **Functional foods** are those that are fortified or enhanced to promote optimal health, above and beyond simply helping the body meet its basic nutritional needs.[5] Functional foods contain (1) enhanced amounts of traditional nutrients, (2) phytochemicals, (3) zoonutrients, or (4) other bioactive components such

phytochemical (also called phytonutrient) (phy – to – CHEM – i – cal) A substance found in plants and thought to benefit human health above and beyond the provision of essential nutrients and energy.

zoonutrient (ZO – o – nu – tri – ent) A substance found in animal foods and thought to benefit human health above and beyond the provision of essential nutrients and energy.

Functional food A food that contains enhanced levels of an essential nutrient, phytochemical, or zoonutrient and thought to benefit human health.

as probiotics (live bacteria). For example, beets are considered a functional food because they contain pigments (colorful compounds) that may reduce inflammation. Another example is yogurt, which has live bacteria thought to impact the immune system. Although consuming functional foods may improve your health, the mechanisms by which this occurs are often poorly understood and require continued research.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Why might scientists consider this bowl of Ukrainian borscht (which contains beets) a functional food?

1-2 What Are the Major Nutrient Classes?

Nutrients are needed by your body to provide structure, regulate chemical reactions (metabolism), and supply energy. Protein, for example, is important for providing the basic structure of muscles, many vitamins help regulate the hundreds of chemical reactions that occur in your body, and dietary fats provide an important source of energy needed to power your body's activities. Each class of nutrients consists of many different compounds and contributes to most of these functions in one way or another. You will learn more about each of the nutrient classes in upcoming chapters.

Carbohydrates Are Vital For Energy and Regulatory Roles

Carbohydrates consist of carbon, hydrogen, and oxygen atoms and serve a variety of functions in the body. There are many different types of carbohydrates, and those found in starchy foods like rice and pasta are quite different from those found in fruits and sweet desserts. Of the various carbohydrates that exist, perhaps the most important is glucose since most cells use glucose as their primary source of energy. Your body uses carbohydrates for many other purposes as well. For instance, some are needed to make the genetic material (DNA) in cells. Other carbohydrates such as dietary fiber play roles in maintaining the health of your digestive system and may help decrease your risk of certain conditions, including heart disease and type 2 diabetes. Carbohydrates are also important structural and regulatory components of the membranes that surround the millions of cells in your body.


Polara Studios

Grains and cereals provide most of the carbohydrates in the diet.

Proteins Make Up Muscles and Are Important For Energy and Regulation

Protein is abundant in many foods, including meat, eggs, dairy products, legumes (such as dried peas), and some whole-grain cereal products. Most proteins consist primarily of carbon, oxygen, nitrogen, and hydrogen atoms, but some also contain sulfur or selenium atoms. The thousands of proteins in your body have numerous roles in addition to serving as a source of energy. Proteins also comprise the major structural material in various parts of your body, including muscle, bone, and skin. Proteins allow us to move, support our


mangpor2004/Shutterstock.com

There are many good sources of protein in the diet, including milk.