WARDLAW'S

Perspectives in

NUTRITION

ELEVENTH EDITION

Carol Byrd-Bredbenner

Gaile Moe

Jacqueline Berning

Danita Kelley

Mc Graw Hill Education

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Brief Contents

Meet the Author Team

Carol Byrd-Bredbenner, Ph.D., R.D., FAND, received her doctorate from Pennsylvania State University. Currently, she is Distinguished Professor in the Nutritional Sciences Department at Rutgers, The State University of New Jersey. She teaches a wide range of undergraduate and graduate nutrition courses. Her research interests focus on investigating environmental factors that affect dietary choices and health outcomes. Dr. Byrd-Bredbenner has authored numerous nutrition texts, journal articles, and computer software packages. She has received teaching awards from the American Dietetic Association (now called the Academy of Nutrition and Dietetics), Society for Nutrition Education, and U.S. Department of Agriculture. She was the recipient of the American Dietetic Association's Anita Owen Award for Innovative Nutrition Education Programs, American Society for Nutrition's Excellence in Nutrition Education Award, and Society for Nutrition Education and Behavior's Helen Denning Ullrich Award for Lifetime Excellence in Nutrition Education. She also was a Fellow of the United Nations, World Health Organization at the WHO Collaborating Center for Nutrition Education, University of Athens, Greece. She enjoys exploring food and culinary customs, traveling, diving, and gardening.

Gaile L. Moe, Ph.D., R.D., earned a doctorate in nutritional sciences at the University of Washington. She is a registered dietitian who has worked in clinical nutrition, research, and management, as well as dietetics education. She previously directed the Didactic Program in Dietetics at Seattle Pacific University and now serves as the Director of General Education. She has published in peer-reviewed journals in the areas of nutrition and cancer and media reporting of nutrition research. She enjoys swimming, cycling, walking, and hiking, along with learning about culinary traditions, food, and food policy.

Jacqueline R. Berning, Ph.D., R.D., CSSD, earned her doctorate in nutrition from Colorado State University in Fort Collins, Colorado. She is currently Professor and Chair of the Health Science Department at the University of Colorado at Colorado Springs (UCCS), where she has won numerous teaching awards. Dr. Berning is published in the area of sports dietetics and was the sport dietitian for the Denver Broncos for over 25 years, Cleveland Indians for 18 years, and Colorado Rockies for 10 years. Currently, she is the sport dietitian for UCCS athletics and US Lacrosse. She is active in the Academy of Nutrition and Dietetics, where she served as Chair of the Program Planning Committee for FNCE and is currently Chair of the Appeals Committee. In 2014, Dr. Berning was awarded the Mary Abbot Hess Award for Culinary Events for teaching the University of Colorado football team how to grocery shop and cook. Additionally, she served 6 years as an ADA spokesperson and is former Chair of the Sports, Cardiovascular, and Wellness Nutritionists dietetics practice group. She enjoys walking, hiking, and gardening.

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Danita Saxon Kelley, Ph.D., R.D., earned her doctorate in nutritional sciences from the University of Kentucky. She serves as Associate Dean of the College of Health and Human Services and is a Professor in the Family and Consumer Sciences Department at Western Kentucky University. Previously, Dr. Kelley was Director of the Didactic Program in Dietetics at Western Kentucky University. She is a Past President of the Board of Directors for the Kentucky Academy of Nutrition and Dietetics. Her scholarly work has focused on healthy eating of adolescents, communication skills of dietetic students, histaminergic activity and regulation of food intake, and dietary restriction effects on the antioxidant defense system. She has received awards for teaching from the Kentucky Academy of Nutrition and Dietetics and the Dietetic Educators of Practitioners of the Academy of Nutrition and Dietetics. She enjoys singing, walking her dog, cheering for her family in water-ski competitions, and watching her children participate in athletic and musical endeavors.

Preface

Welcome to the Eleventh Edition of Wardlaw's Perspectives in Nutrition

Wardlaw's Perspectives in Nutrition has the richly deserved reputation of providing an accurate, current, in-depth, and thoughtful introduction to the dynamic field of nutrition. We have endeavored to build upon this tradition of excellence by enriching this edition for both students and instructors. Our passion for nutrition, our genuine desire to promote student learning, and our commitment to scientific accuracy, coupled with constructive comments from instructors and students, guided us in this effort. Our primary goal has been to maintain the strengths and philosophy that have been the hallmark of this book yet continue to enhance the accessibility of the science content and the application of materials for today's students.

Nutrition profoundly affects all of our lives every day. For the authors, as well as many other educators, researchers, and clinicians, this is the compelling reason for devoting our careers to this dynamic field. The rapid pace of nutrition research and provocative (and sometimes controversial) findings challenge us all to stay abreast of the latest research and understand its implications for health. We invite you to share with us topics that you believe deserve greater or less attention in the next edition.

To your health!

Carol Byrd-Bredbenner

Gaile Moe

Jacqueline Berning

Danita Kelley

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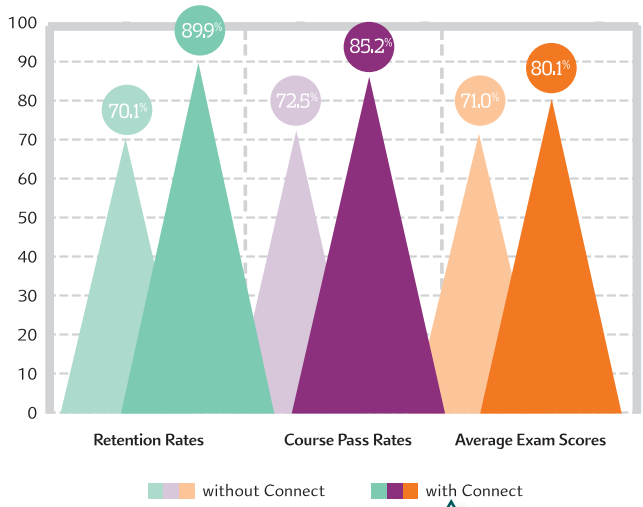

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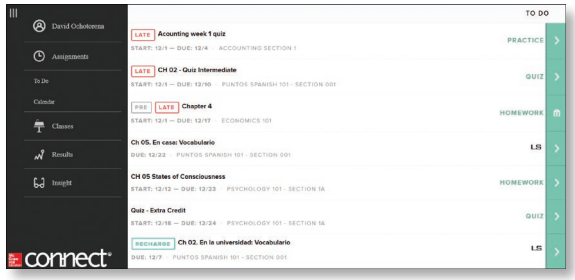

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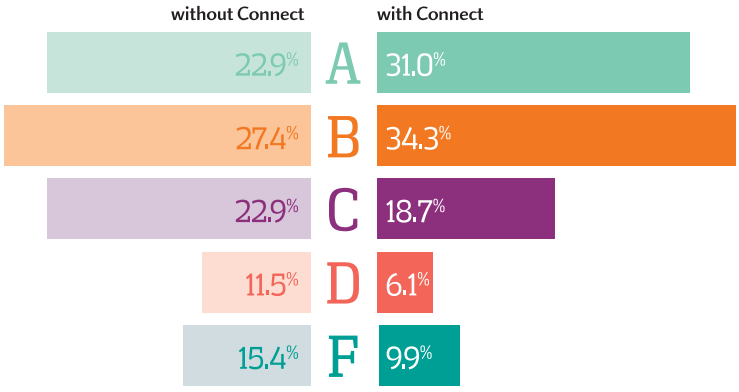

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Connecting Instructors and Students to Additional Digital Resources

Saves students and instructors time while improving performance

McGraw-Hill Campus integrates all of your digital products from McGraw-Hill Education with your school's Learning Management System for quick and easy access to best-in-class content and learning tools.

Dietary Analysis Tool

NutritionCalc Plus is a powerful dietary analysis tool featuring more than 30,000 foods from the ESHA Research nutrient database, which is comprised of data from the latest USDA Standard Reference database, manufacturer's data, restaurant data, and data from literature sources. NutritionCalc Plus allows users to track food and activities, and then analyze their choices with a robust selection of intuitive reports. The interface was updated to accommodate ADA requirements and modern mobile experience native to today's students. This tool is provided complimentary in Connect with *Perspectives in Nutrition*.

Presentation Tools allow you to customize your lectures

Enhanced Lecture Presentations Contain lecture outlines, art, photos, and tables. Fully customizable, adapted for ADA compliance, complete, and ready to use—these presentations will streamline your work and let you spend less time preparing for lecture!

Editable Art Fully editable (labels and leaders) line art from the text

Animations Over 50 animations bring key concepts to life, available for instructors *and* students.

Digital Lecture Capture

Tegrity® is a fully automated lecture capture solution used in traditional, hybrid, "flipped classes" and online courses to record lessons, lectures, and skills.

Connecting Students to Today's Nutrition

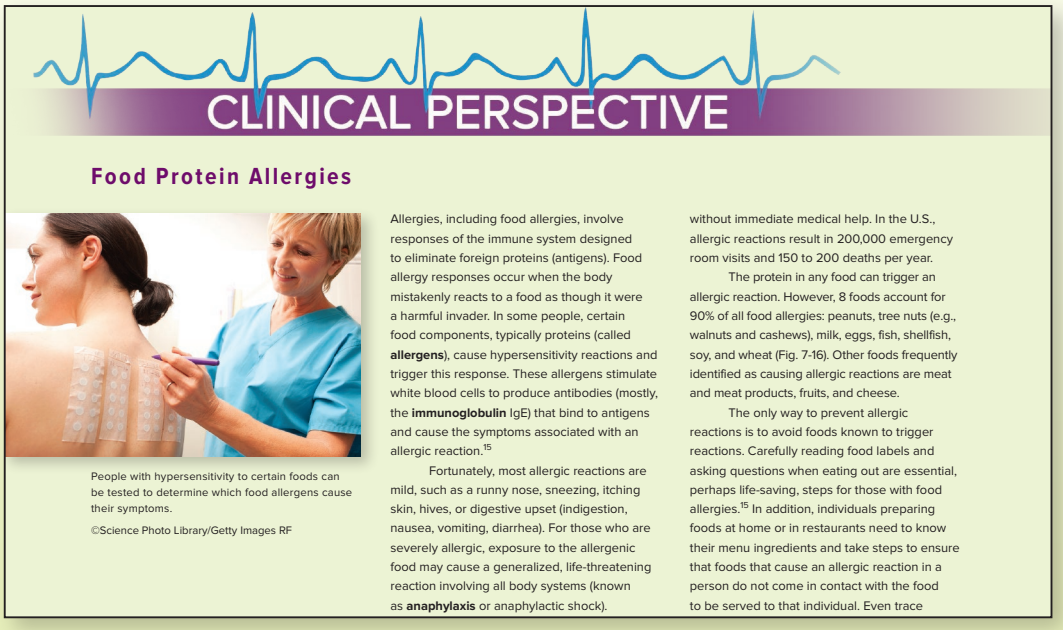
Our Intended Audience

This textbook was developed for students pursuing nutrition and health science careers as well as those wanting a better understanding of how nutrition affects their lives. Because this course often attracts students from a broad range of majors, we have been careful to include examples and explanations that are relevant to them and to include sufficient scientific background to make the science accessible to them. The appendices help students who wish to learn more or need assistance with the science involved in human physiology, chemistry, and metabolism.

To better bridge the span of differing science backgrounds and to enhance student interest and achievement of course objectives, we organized the presentation of the material within chapters to flow seamlessly from concrete to abstract learning. In chapters focusing on nutrients, for example, concrete concepts, such as food sources of the nutrients and recommended intakes, are introduced early in the chapter to create a framework for more abstract concepts, such as functions, digestion, and absorption.

Accurate, Current Science That Engages Students

The eleventh edition continues the tradition of presenting scientific content that is reliable, accurate, and up-to-date. This edition incorporates coverage of recent nutrition research, as well as the recent updates to consumer guidelines and tools—Dietary Guidelines for Americans, MyPlate, *Healthy People 2020,* and the new Nutrition Facts panel. It also retains the in-depth coverage students need to fully understand and appreciate the role of nutrition in overall health and to build the scientific knowledge base needed to pursue health-related careers or simply live healthier lives. To enhance these strengths and promote greater comprehension, new research findings and peer-reviewed references are incorporated and artwork is enhanced to further complement the discussions. The presentation of complex concepts was scrutinized to increase clarity through the use of clear, streamlined, precise, and student-friendly language. Timely and intriguing examples, illustrative analogies, clinical insights, culinary perspectives, historical notes, future perspectives, and thought-provoking photos make the text enjoyable and interesting to students and instructors alike.



CLINICAL PERSPECTIVE

Food Protein Allergies

People with hypersensitivity to certain foods can be tested to determine which food allergens cause their symptoms.

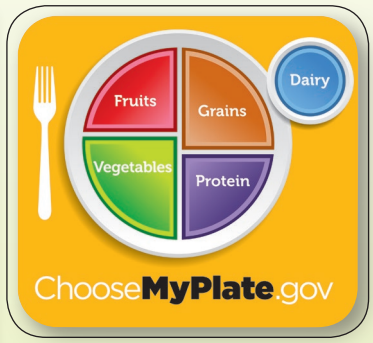
©Science Photo Library/Getty Images RF

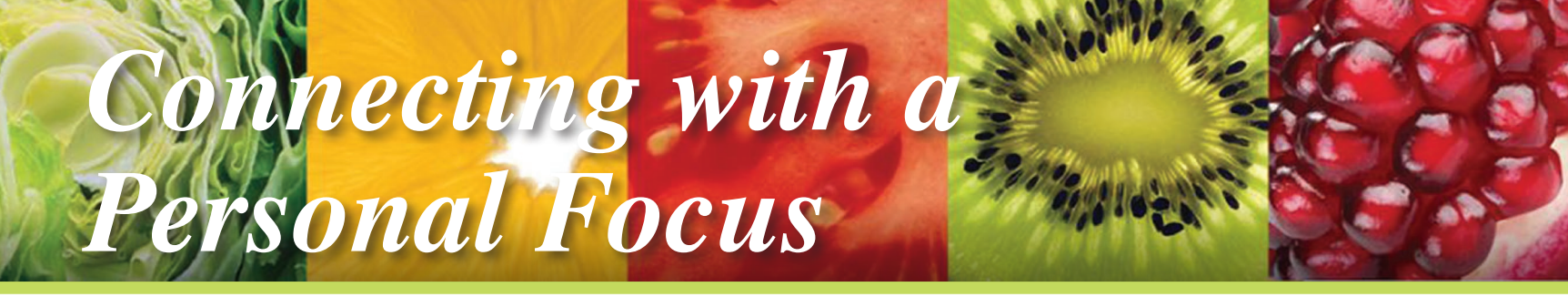
Allergies, including food allergies, involve responses of the immune system designed to eliminate foreign proteins (antigens). Food allergy responses occur when the body mistakenly reacts to a food as though it were a harmful invader. In some people, certain food components, typically proteins (called **allergens**), cause hypersensitivity reactions and trigger this response. These allergens stimulate white blood cells to produce antibodies (mostly, the **immunoglobulin** IgE) that bind to antigens and cause the symptoms associated with an allergic reaction.[15]

Fortunately, most allergic reactions are mild, such as a runny nose, sneezing, itching skin, hives, or digestive upset (indigestion, nausea, vomiting, diarrhea). For those who are severely allergic, exposure to the allergenic food may cause a generalized, life-threatening reaction involving all body systems (known as **anaphylaxis** or anaphylactic shock). without immediate medical help. In the U.S., allergic reactions result in 200,000 emergency room visits and 150 to 200 deaths per year.

The protein in any food can trigger an allergic reaction. However, 8 foods account for 90% of all food allergies: peanuts, tree nuts (e.g., walnuts and cashews), milk, eggs, fish, shellfish, soy, and wheat (Fig. 7-16). Other foods frequently identified as causing allergic reactions are meat and meat products, fruits, and cheese.

The only way to prevent allergic reactions is to avoid foods known to trigger reactions. Carefully reading food labels and asking questions when eating out are essential, perhaps life-saving, steps for those with food allergies.[15] In addition, individuals preparing foods at home or in restaurants need to know their menu ingredients and take steps to ensure that foods that cause an allergic reaction in a person do not come in contact with the food to be served to that individual. Even trace



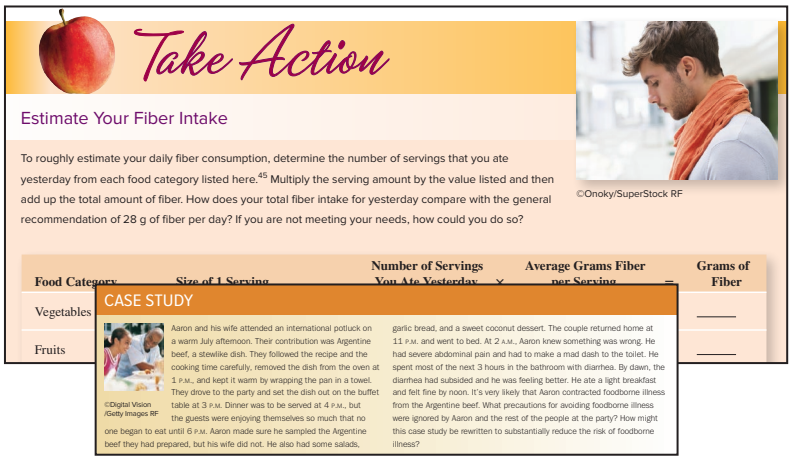


Connecting with a Personal Focus

Applying Nutrition on a Personal Level

A key objective in nearly all introductory courses is for students to apply their new knowledge of nutrition to their own lives. Practical applications clearly linked to nutritional science concepts are woven throughout each chapter to help students apply their knowledge to improving and maintaining their own health and that of others for whom they are responsible, such as future patients or offspring.

- **Take Action** features in each chapter allow students to examine their own diets and health issues.
- Updated **case studies** showcase realistic scenarios and thought-provoking questions.
- New discussion of the Nutrition Facts panel outlines the innovative changes to this important consumer tool.



Take Action

Estimate Your Fiber Intake

To roughly estimate your daily fiber consumption, determine the number of servings that you ate yesterday from each food category listed here.[45] Multiply the serving amount by the value listed and then add up the total amount of fiber. How does your total fiber intake for yesterday compare with the general recommendation of 28 g of fiber per day? If you are not meeting your needs, how could you do so?

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Food Category	Size of 1 Serving	Number of Servings You Ate Yesterday	×	Average Grams Fiber per Serving	=	Grams of Fiber
Vegetables						____
Fruits						____

CASE STUDY

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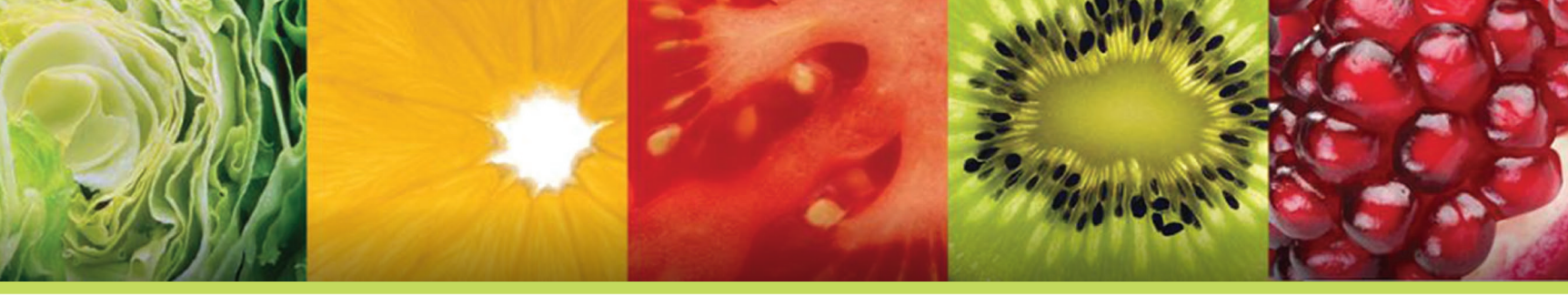
Aaron and his wife attended an international potluck on a warm July afternoon. Their contribution was Argentine beef, a stewlike dish. They followed the recipe and the cooking time carefully, removed the dish from the oven at 1 P.M., and kept it warm by wrapping the pan in a towel. They drove to the party and set the dish out on the buffet table at 3 P.M. Dinner was to be served at 4 P.M., but the guests were enjoying themselves so much that no one began to eat until 6 P.M. Aaron made sure he sampled the Argentine beef they had prepared, but his wife did not. He also had some salads, garlic bread, and a sweet coconut dessert. The couple returned home at 11 P.M. and went to bed. At 2 A.M., Aaron knew something was wrong. He had severe abdominal pain and had to make a mad dash to the toilet. He spent most of the next 3 hours in the bathroom with diarrhea. By dawn, the diarrhea had subsided and he was feeling better. He ate a light breakfast and felt fine by noon. It's very likely that Aaron contracted foodborne illness from the Argentine beef. What precautions for avoiding foodborne illness were ignored by Aaron and the rest of the people at the party? How might this case study be rewritten to substantially reduce the risk of foodborne illness?

Applying Nutrition to Career and More

- ***Expert Perspectives from the Field*** features examine cutting-edge topics and demonstrate how emerging, and sometimes controversial, research results affect nutrition knowledge and practice.
- ***Clinical Perspectives*** highlight the role of nutrition in the prevention and treatment of disease. These topics will be especially interesting to students planning careers in dietetics or health-related fields.
- ***Global Perspectives*** discuss concepts related to critical health and nutrition issues around the world. These timely features also aim to engage students with thought-provoking challenges.
- ***Historical Perspectives*** heighten awareness of critical discoveries and events that have affected our understanding of nutritional science.
- ***Perspective on the Future*** features address emerging trends affecting nutrition science and practice.
- ***Culinary Perspectives*** focus on interesting food trends and their impact on health.
- Each major heading in the chapters is numbered and cross-referenced to the end-of-chapter summary and study questions to make it easy to locate and prioritize important concepts.



HISTORICAL PERSPECTIVE

Photographing Atoms

Discovering the molecular layout of biologically important molecules is critical to understanding their function and treating disease. The biochemist and crystallographer Dorothy Crowfoot Hodgkin developed new X-ray techniques that permitted her to determine the structure of over 100 molecules, including insulin, vitamin B-12, vitamin D, and penicillin. Her work with insulin improved treatment of diabetes. Knowing the structure of vitamin B-12 advanced our knowledge of its role in blood health. Learn more about this Nobel Prize winner at www.nobelprize.org/nobel_prizes/chemistry/laureates/1964/hodgkin-bio.htm

Perspective on the Future

The common wisdom that eating 3500 kcal less than you need will result in the loss of 1 pound has come under great scrutiny. Weight loss research models based on thermodynamics, mathematics, physics, and chemistry indicate many more than 3500 calories may be stored in a pound of body fat. Researchers are working to build and validate more accurate weight loss prediction models.[57] Learn more at www.pbrc.edu/research-and-faculty/calculators/weight-loss-predictor.

Expert Perspective from the Field

Tailoring a Healthy Eating Plan to Fit Your Lifestyle

According to Dr. Judith Rodriguez,* find
your lifestyle is the key to controlling w
In her book *The Diet Selector,* Dr. Rodr
common principles to help consumers
diets. Find what you like to eat or the c

CLINICAL PERSPECTIVE

Foodborne Illness Can Be

Foodborne illness often means a few hours or even a few days of discomfort and then the illness resolves on its own. In some cases, though, foodborne illness causes more serious medical problems, which can have lifelong

GLOBAL PERSPECTIVE

How Big Is Your Food Print?

Growing evidence indicates that what we eat may affect not only our personal health but also that of the environment. The world population is projected to increase to over 9 billion by 2050. The Food and Agricultural Organization (FAO) projects that food and feed production will need to increase by 70% to adequately feed the world's population. Many scientists believe that meat rich diets and the agricultural practices that support the production of food for these diets negatively affect the environment. For instance, producing food for nonvegetarian diets (especially beef-based diets) uses more water, fossil fuel energy, and acres of farmland than producing food for vegetarian diets.[29] Meat rich diets also cause greater emissions of greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, which are associated with global warming.[30] Scientists are concerned that continued population growth may, in turn, decrease agricultural productivity, reduce farmers' incomes, and increase global food insecurity.[31]

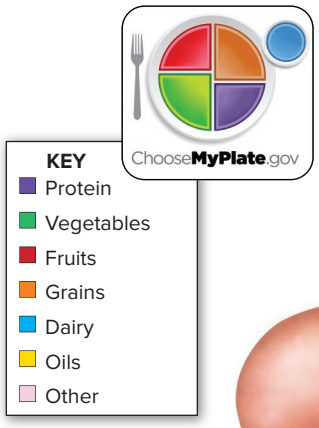
Not all scientists agree with these findings and concerns, however. Some believe that consuming a low-fat vegetarian diet with some dairy products and/or meat may actually increase land use efficiency, thereby protecting environmental resources and promoting food security.[32] They point out that high quality farmland is required to grow fruits, vegetables, and grains, whereas meat and dairy products can be produced on the more widely available, lower quality land. Even though diets containing meat use more land, they can feed more people because of the greater availability of lower quality farmland. It appears that diets have different "agricultural land footprints," depending on the amount of plant-based and animal-based food they contain. Supporters of mixed animal/vegetable–based diets point out that vegetarian diets often include tofu and other meat substitutes produced from soy, chickpeas, and lentils. Many meat substitutes are highly processed and require energy-intensive production methods. Thus, including small amounts of meat may offer both environmental and nutritional benefits.

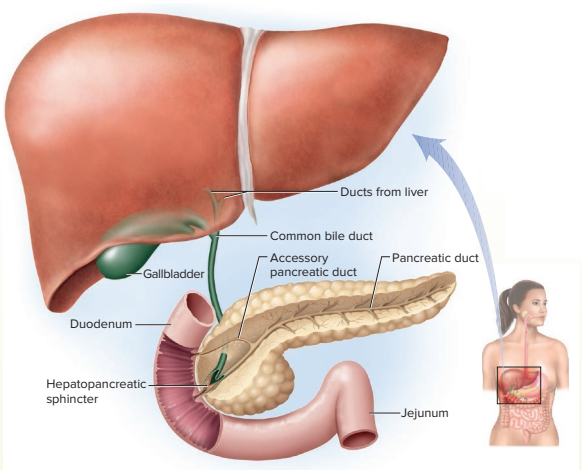
Making Visual Connections

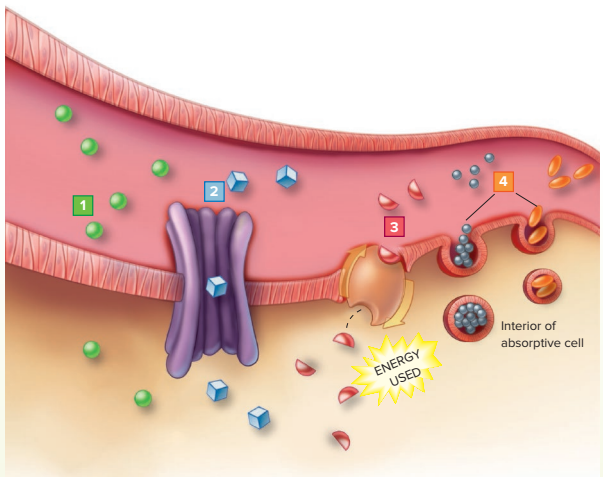
Dynamic, Accurate Artwork

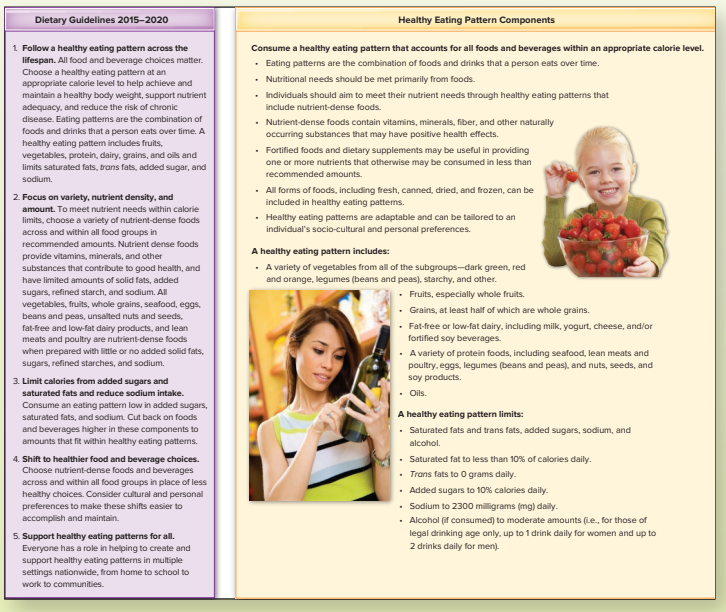
More than 1000 drawings, photographs, and tables in the text were critically analyzed to identify how each could be enhanced and refined to help students more easily master complex scientific concepts.

- Many illustrations were updated or replaced to inspire student inquiry and comprehension and to promote interest and retention of information.
- Many illustrations were redesigned to use brighter colors and a more attractive, contemporary style. Others were fine-tuned to make them clearer and easier to follow. Navigational aids show where a function occurs and put it in perspective of the whole body.
- Coordinated color schemes and drawing styles keep presentations consistent and strengthen the educational value of the artwork. Color-coding and directional arrows in figures make it easier to follow events and reinforce interrelationships.









Dietary Guidelines 2015–2020

1. **Follow a healthy eating pattern across the lifespan.** All food and beverage choices matter. Choose a healthy eating pattern at an appropriate calorie level to help achieve and maintain a healthy body weight, support nutrient adequacy, and reduce the risk of chronic disease. Eating patterns are the combination of foods and drinks that a person eats over time. A healthy eating pattern includes fruits, vegetables, protein, dairy, grains, and oils and limits saturated fats, *trans* fats, added sugar, and sodium.
2. **Focus on variety, nutrient density, and amount.** To meet nutrient needs within calorie limits, choose a variety of nutrient-dense foods across and within all food groups in recommended amounts. Nutrient dense foods provide vitamins, minerals, and other substances that contribute to good health, and have limited amounts of solid fats, added sugars, refined starch, and sodium. All vegetables, fruits, whole grains, seafood, eggs, beans and peas, unsalted nuts and seeds, fat-free and low-fat dairy products, and lean meats and poultry are nutrient-dense foods when prepared with little or no added solid fats, sugars, refined starches, and sodium.
3. **Limit calories from added sugars and saturated fats and reduce sodium intake.** Consume an eating pattern low in added sugars, saturated fats, and sodium. Cut back on foods and beverages higher in these components to amounts that fit within healthy eating patterns.
4. **Shift to healthier food and beverage choices.** Choose nutrient-dense foods and beverages across and within all food groups in place of less healthy choices. Consider cultural and personal preferences to make these shifts easier to accomplish and maintain.
5. **Support healthy eating patterns for all.** Everyone has a role in helping to create and support healthy eating patterns in multiple settings nationwide, from home to school to work to communities.

Healthy Eating Pattern Components

Consume a healthy eating pattern that accounts for all foods and beverages within an appropriate calorie level.

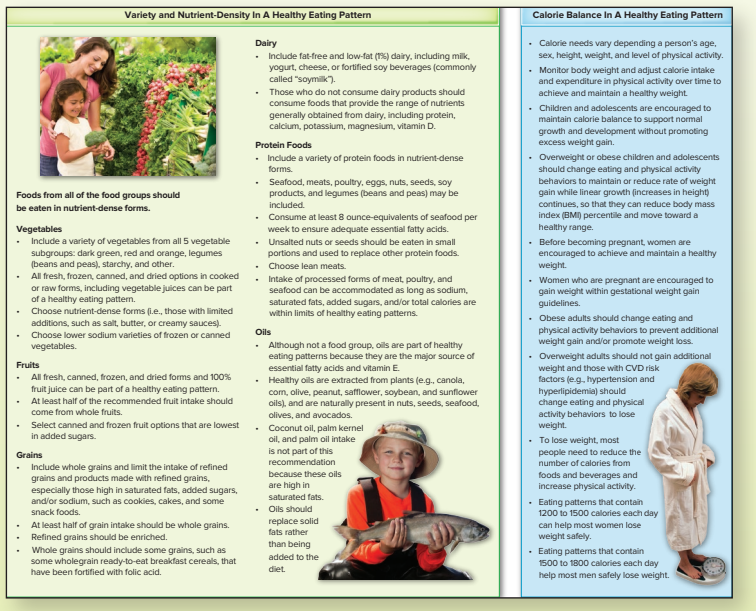
- Eating patterns are the combination of foods and drinks that a person eats over time.
- Nutritional needs should be met primarily from foods.
- Individuals should aim to meet their nutrient needs through healthy eating patterns that include nutrient-dense foods.
- Nutrient-dense foods contain vitamins, minerals, fiber, and other naturally occurring substances that may have positive health effects.
- Fortified foods and dietary supplements may be useful in providing one or more nutrients that otherwise may be consumed in less than recommended amounts.
- All forms of foods, including fresh, canned, dried, and frozen, can be included in healthy eating patterns.
- Healthy eating patterns are adaptable and can be tailored to an individual's socio-cultural and personal preferences.

A healthy eating pattern includes:

- A variety of vegetables from all of the subgroups—dark green, red and orange, legumes (beans and peas), starchy, and other.
- Fruits, especially whole fruits.
- Grains, at least half of which are whole grains.
- Fat-free or low-fat dairy, including milk, yogurt, cheese, and/or fortified soy beverages.
- A variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), and nuts, seeds, and soy products.
- Oils.

A healthy eating pattern limits:

- Saturated fats and trans fats, added sugars, sodium, and alcohol.
- Saturated fat to less than 10% of calories daily.
- *Trans* fats to 0 grams daily.
- Added sugars to 10% calories daily.
- Sodium to 2300 milligrams (mg) daily.
- Alcohol (if consumed) to moderate amounts (i.e., for those of legal drinking age only, up to 1 drink daily for women and up to 2 drinks daily for men).



Variety and Nutrient-Density In A Healthy Eating Pattern

Foods from all of the food groups should be eaten in nutrient-dense forms.

Vegetables

- Include a variety of vegetables from all 5 vegetable subgroups: dark green, red and orange, legumes (beans and peas), starchy, and other.
- All fresh, frozen, canned, and dried options in cooked or raw forms, including vegetable juices can be part of a healthy eating pattern.
- Choose nutrient-dense forms (i.e., those with limited additions, such as salt, butter, or creamy sauces).
- Choose lower sodium varieties of frozen or canned vegetables.

Fruits

- All fresh, canned, frozen, and dried forms and 100% fruit juice can be part of a healthy eating pattern.
- At least half of the recommended fruit intake should come from whole fruits.
- Select canned and frozen fruit options that are lowest in added sugars.

Grains

- Include whole grains and limit the intake of refined grains and products made with refined grains, especially those high in saturated fats, added sugars, and/or sodium, such as cookies, cakes, and some snack foods.
- At least half of grain intake should be whole grains.
- Refined grains should be enriched.
- Whole grains should include some grains, such as some wholegrain ready-to-eat breakfast cereals, that have been fortified with folic acid.

Dairy

- Include fat-free and low-fat (1%) dairy, including milk, yogurt, cheese, or fortified soy beverages (commonly called "soymilk").
- Those who do not consume dairy products should consume foods that provide the range of nutrients generally obtained from dairy, including protein, calcium, potassium, magnesium, vitamin D.

Protein Foods

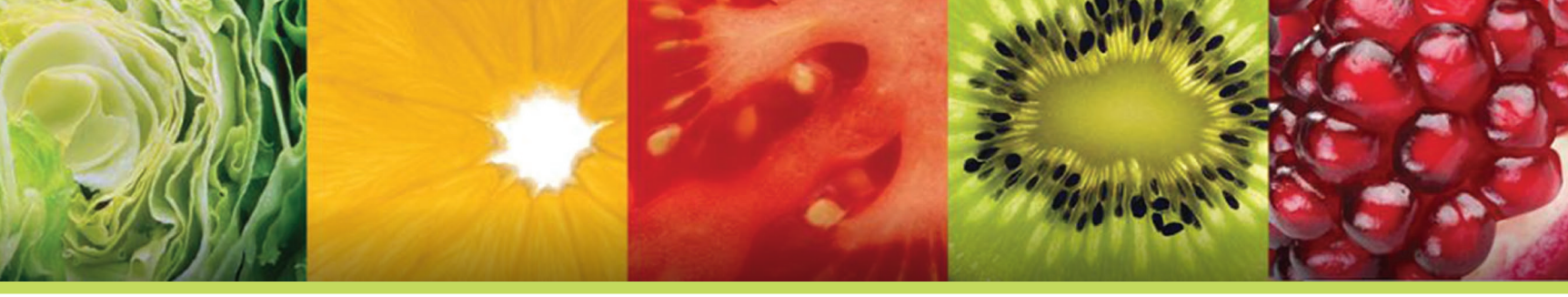
- Include a variety of protein foods in nutrient-dense forms.
- Seafood, meats, poultry, eggs, nuts, seeds, soy products, and legumes (beans and peas) may be included.
- Consume at least 8 ounce-equivalents of seafood per week to ensure adequate essential fatty acids.
- Unsalted nuts or seeds should be eaten in small portions and used to replace other protein foods.
- Choose lean meats.
- Intake of processed forms of meat, poultry, and seafood can be accommodated as long as sodium, saturated fats, added sugars, and/or total calories are within limits of healthy eating patterns.

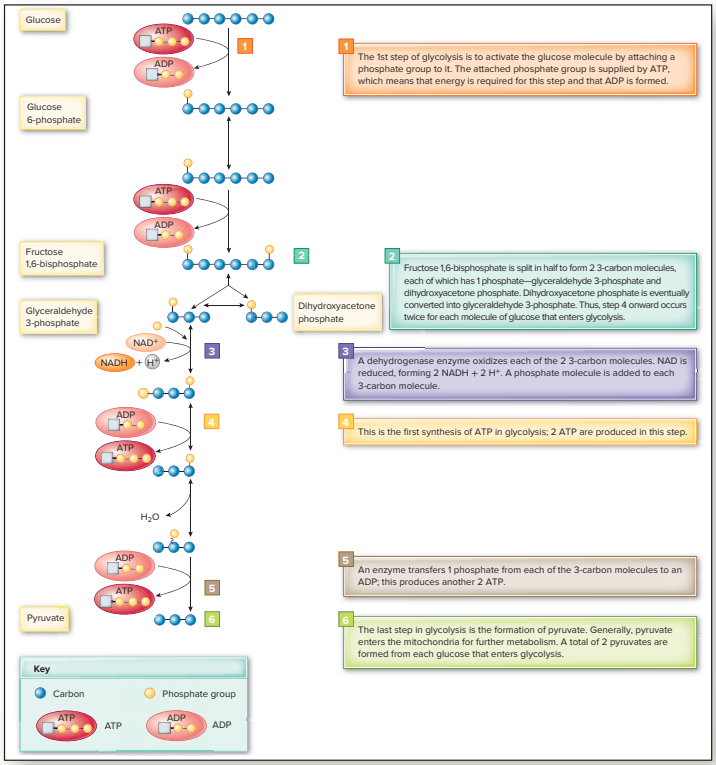
Oils

- Although not a food group, oils are part of healthy eating patterns because they are the major source of essential fatty acids and vitamin E.
- Healthy oils are extracted from plants (e.g., canola, corn, olive, peanut, safflower, soybean, and sunflower oils), and are naturally present in nuts, seeds, seafood, olives, and avocados.
- Coconut oil, palm kernel oil, and palm oil intake is not part of this recommendation because these oils are high in saturated fats.
- Oils should replace solid fats rather than being added to the diet.

Calorie Balance In A Healthy Eating Pattern

- Calorie needs vary depending a person's age, sex, height, weight, and level of physical activity.
- Monitor body weight and adjust calorie intake and expenditure in physical activity over time to achieve and maintain a healthy weight.
- Children and adolescents are encouraged to maintain calorie balance to support normal growth and development without promoting excess weight gain.
- Overweight or obese children and adolescents should change eating and physical activity behaviors to maintain or reduce rate of weight gain while linear growth (increases in height) continues, so that they can reduce body mass index (BMI) percentile and move toward a healthy range.
- Before becoming pregnant, women are encouraged to achieve and maintain a healthy weight.
- Women who are pregnant are encouraged to gain weight within gestational weight gain guidelines.
- Obese adults should change eating and physical activity behaviors to prevent additional weight gain and/or promote weight loss.
- Overweight adults should not gain additional weight and those with CVD risk factors (e.g., hypertension and hyperlipidemia) should change eating and physical activity behaviors to lose weight.
- To lose weight, most people need to reduce the number of calories from foods and beverages and increase physical activity.
- Eating patterns that contain 1200 to 1500 calories each day can help most women lose weight safely.
- Eating patterns that contain 1500 to 1800 calories each day help most men safely lose weight.

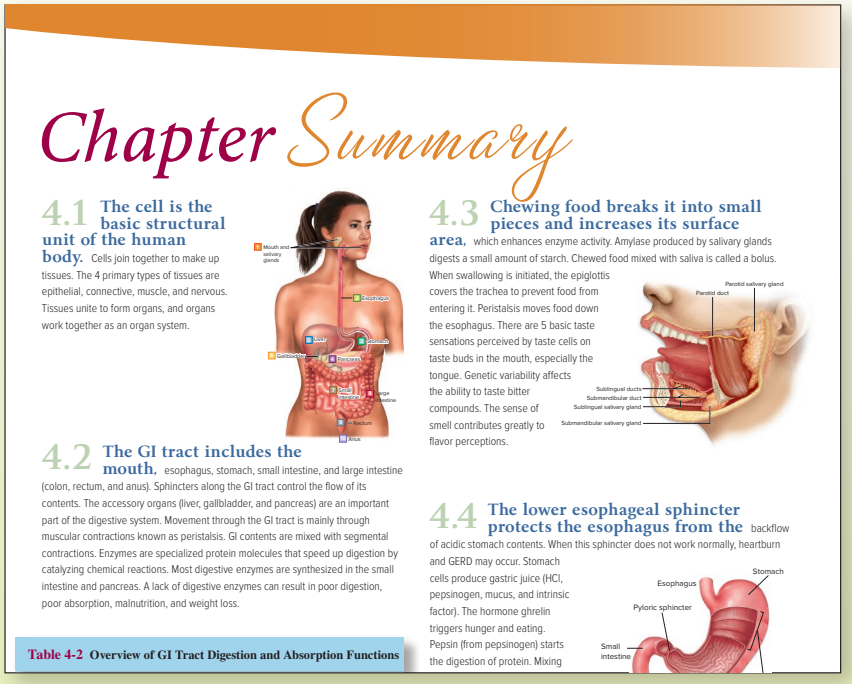




- In many figures, process descriptions appear in the body of the figure. This pairing of the action and an explanation walks students step-by-step through the process and increases the teaching effectiveness of these figures.
- Intriguing chapter opening photos pique students' curiosity by featuring seemingly unrelated topics that draw connections between the photo and nutrition.
- Finally, a careful comparison of artwork with its corresponding text was done to ensure that they are completely coordinated and consistent. The final result is a striking visual program that holds readers' attention and supports the goals of clarity, ease of comprehension, and critical thinking. The attractive layout and design of this edition are clean, bright, and inviting. This creative presentation of the material is geared toward engaging today's visually oriented students.

Illustrative Chapter Summary

The visual chapter summary continues to reinforce key concepts and promote student engagement and comprehension.



Chapter Summary

4.1 The cell is the basic structural unit of the human body. Cells join together to make up tissues. The 4 primary types of tissues are epithelial, connective, muscle, and nervous. Tissues unite to form organs, and organs work together as an organ system.

4.2 The GI tract includes the mouth, esophagus, stomach, small intestine, and large intestine (colon, rectum, and anus). Sphincters along the GI tract control the flow of its contents. The accessory organs (liver, gallbladder, and pancreas) are an important part of the digestive system. Movement through the GI tract is mainly through muscular contractions known as peristalsis. GI contents are mixed with segmental contractions. Enzymes are specialized protein molecules that speed up digestion by catalyzing chemical reactions. Most digestive enzymes are synthesized in the small intestine and pancreas. A lack of digestive enzymes can result in poor digestion, poor absorption, malnutrition, and weight loss.

Table 4-2 Overview of GI Tract Digestion and Absorption Functions

4.3 Chewing food breaks it into small pieces and increases its surface area, which enhances enzyme activity. Amylase produced by salivary glands digests a small amount of starch. Chewed food mixed with saliva is called a bolus. When swallowing is initiated, the epiglottis covers the trachea to prevent food from entering it. Peristalsis moves food down the esophagus. There are 5 basic taste sensations perceived by taste cells on taste buds in the mouth, especially the tongue. Genetic variability affects the ability to taste bitter compounds. The sense of smell contributes greatly to flavor perceptions.

4.4 The lower esophageal sphincter protects the esophagus from the backflow of acidic stomach contents. When this sphincter does not work normally, heartburn and GERD may occur. Stomach cells produce gastric juice (HCl, pepsinogen, mucus, and intrinsic factor). The hormone ghrelin triggers hunger and eating. Pepsin (from pepsinogen) starts the digestion of protein. Mixing

Connecting with the Latest Updates

Global Updates and Changes

- The entire eleventh edition has been updated, refined, and streamlined to enhance learning.
- Complete Nutrition Facts panel updated to include latest regulations
- Incorporation of new Daily Values in charts demonstrating nutrient content
- New *Culinary Perspective* feature throughout the eleventh edition
- All Dietary Reference Intakes (RDA, AI, UL, EAR, and AMDR) grouped into 1 appendix for quick and easy access

Chapter 1, *The Science of Nutrition*

- Updated statistics on leading causes of death
- Fresh, new photos for visual engagement
- Section introducing how to navigate scientific journal articles to enhance student self-confidence in using these materials
- New FDA guidance to the dietary supplement industry introduced

Chapter 2, *Tools of a Healthy Diet*

- Complete Nutrition Facts panel updated to include latest regulations
- Application of Dietary Reference Intakes (DRIs) to federal nutrition programs incorporated
- Extensive revision of Table 2-2 to include the newly released Daily Value (DV) updates
- All images of the Nutrition Facts panel replaced to show the new format
- Updated coverage of the new restaurant menu labeling regulations
- Figure summarizing the Dietary Guidelines for Americans (Figure 2-6) refined to facilitate reading ease and comprehension.
- Incorporated most recent updates to MyPlate that were made based on the Dietary Guidelines for Americans 2015–2020
- Added latest guidance on added sugar maximums (Table 2-6)

Chapter 3, *The Food Supply*

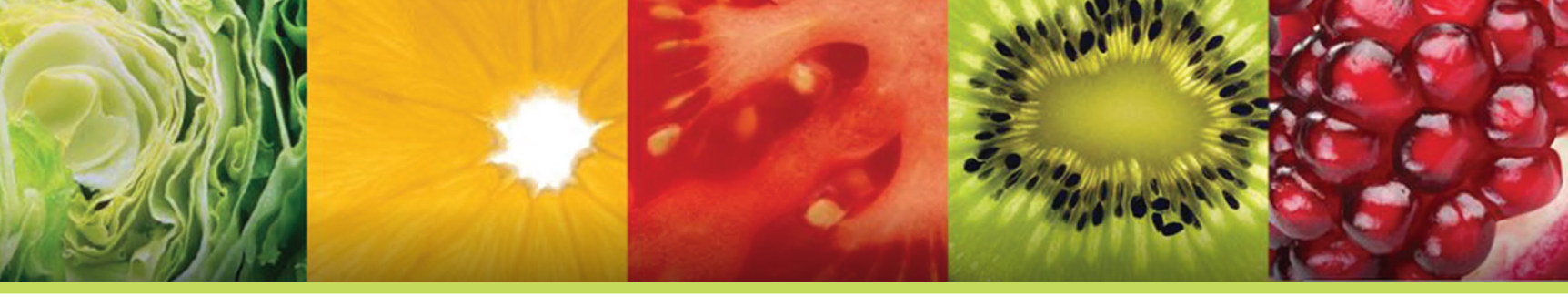
- Updated domestic and international food insecurity statistics highlighting the worldwide burden of malnutrition and hunger
- Enhanced discussion on food deserts
- Addition of the effects of the Syrian civil war on food insecurity
- New discussion of the impact of food waste on global food insecurity
- Expanded discussion of the nutritional benefits of foods grown using conventional vs. organic farming practices
- Extensive revision of discussion of biotechnology, genetically modified foods and animals, production methods (such as gene editing), regulations, and safety
- New example of how intentional food additives are used in typically consumed foods
- Enhanced discussion of safety concerns associated with incidental additives, such as arsenic, pesticide residues, and BPA
- Latest CDC foodborne illness statistics included
- Updates to foodborne illness food sources, symptoms, and transmission incorporated into key chapter tables (Tables 3-4, 3-5, 3-6, and 3-7)
- Fully updated discussion of prions
- Discussion of water contamination in Flint, Michigan, added
- Overhauled discussion of lead poisoning
- New section on arsenic in the food supply and the contributions of rice
- Extensive revision of discussion of polychlorinated biphenyls (PCBs) in the food supply
- New table (Table 3-9) summarizing guidelines to help children and pregnant and breastfeeding women limit mercury in the diet
- New *Expert Perspective from the Field* on sustainability in university food service

Chapter 4, *Human Digestion and Absorption*

- Enhanced discussion on taste perception, super tasters, and PROP
- Added explanation of the functions of the stomach during digestion and incorporated it into Table 4-4 as a regulatory hormone of the GI tract
- Incorporated role of ghrelin in regulation of food intake
- Update of the *Global Perspective* to include latest global data on child death from diarrhea
- Extensive revision of gut microbiota section to incorporate the latest discoveries in this rapidly changing area of scientific study
- Discussion of probiotics and prebiotics expanded
- New *Culinary Perspective* featuring fermented foods
- Low FODMAP diet introduced
- New section on nonalcoholic fatty liver disease exploring this increasingly common disorder

Chapter 5, *Carbohydrates*

- New photo of stevia added
- *Take Action* revised to increase student engagement
- Statistics on carbohydrate and sugar consumption revised
- Figures updated to show the newest Nutrition Facts panels



- Role of whole grains in reducing obesity risk, enhancing blood glucose control, and reducing cholesterol absorption added
- Extensive revision of Figure 5-17 to enhance student understanding of blood glucose regulation

Chapter 6, *Lipids*

- Triglyceride section headers refined to increase clarity
- Enhanced labeling of type and health effects of fatty acids (Table 6-1)
- Refined figure of adipose cell importing triglycerides
- Streamlined discussion body fat's role in insulating the body
- Updated saturated fat intakes to Institute of Medicine recommendations
- Discussion of saturated fat intake revised to reflect recent research findings and expert guidance
- Figure 6-17 caption refined to promoting increased comprehension of differences in lipoprotein structure and composition

Chapter 7, *Proteins*

- New discussion on pulses as a key component of vegetarian diets and as sustainable crops
- Enhanced image of normal and sickle red blood cells
- New *Knowledge Check* items for sources of protein
- Refined fluid balance depiction (Figure 7-14) to enhance clarity
- Latest statistics on protein-energy malnutrition incorporated
- Revised food allergy prevention discussion to reflect the latest guidance
- Updated *Global Perspective* to reflect most current population projections

Chapter 8, *Alcohol*

- Alcohol standard sizes updated to use alcoholic drink equivalents
- Addition of equation demonstrating calculation of alcohol drink equivalents
- Terminology updated to use DSM-5 recommendations of "alcohol use disorder"
- Alcohol consumption trends and statistics updated
- New *Culinary Perspective* explores cooking with alcohol and alcohol burn-off and retention by food preparation method
- Newly available powdered alcohol described
- New section on college and underage drinking included
- Extensive revision of table on the impact of harmful and underage college drinking (Table 8-4)
- Dangers of combining alcohol and caffeine added
- Updated cirrhosis section to reflect newest research
- New table summarizing DSM-5 diagnostic criteria for an alcohol use disorder added
- Enhanced discussion of ethnicity and alcohol abuse
- New section on economic costs of alcohol abuse included
- Streamlined *Clinical Perspective* to focus on treatment of alcohol use disorders
- Improved labeling of figure showing carnitine shuttling fatty acids into mitochondria (Figure 9-12)
- New figure illustrating the J-shaped relation between alcohol intake and health risks
- Statistics on fetal alcohol spectrum disorders updated

Chapter 9, *Energy Metabolism*

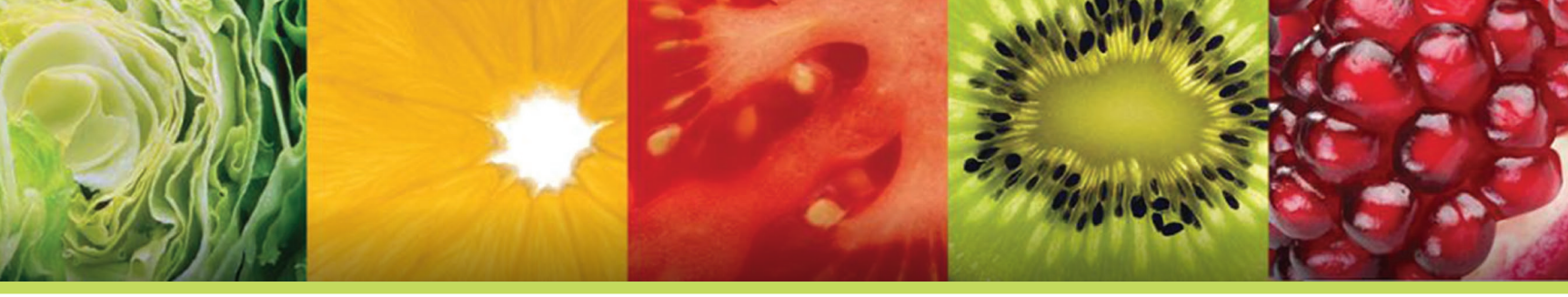
- Improved clarity of image explaining ATP structure (Figure 9-3)
- Refined image depicting ATP storing and yielding energy (Figure 9-4)
- Enhanced visual quality of figure demonstrating aerobic carbohydrate metabolism (Figure 9-5)
- Improved explanatory aspects of image explaining glycolysis (Figure 9-7)
- Modified alcohol metabolism figure to enhance student understanding (Figure 9-19)
- New *Critical Thinking* added
- Revised *Knowledge Check* items to promote learning
- Refined visual summary of the liver's role in metabolism (Figure 9-21)

Chapter 10, *Energy Balance, Weight Control, and Eating Disorders*

- Most up-to-date map of obesity rates in the U.S.
- Latest statistics on high fructose corn syrup consumption added
- Addition of sleep deprivation as a factor influencing hunger feelings
- Newest fad diets incorporated into Table 10-7
- New headings added to guide study of eating behavior regulation
- Newest statistics on prevalence and susceptibility of disordered eating
- Eating disorders section enhanced to describe types of anorexia nervosa
- Section on binge eating disorder added
- Other Specified Feeding and Eating Disorders updated and expanded to reflect latest diagnostic criteria (DSM-5)

Chapter 11, *Nutrition, Exercise, and Sports*

- Section added on Relative Energy Deficiency in Sport (REDS)
- Updated procedures for cooling the body when heat exhaustion occurs
- Latest recommendations for use of sports drinks incorporated



Chapter 12, *The Fat-Soluble Vitamins*

- Updated food sources of vitamin A (Figure 12-3) to reflect latest Daily Values
- Nutrition Facts labeling changes for vitamin A incorporated
- Links noted between beta-carotene and alpha-carotene's role in breast cancer risk reduction from the European Prospective Investigation into Cancer (EPIC) and Nurses' Health Study discussed
- Expanded discussion on possible links between beta-carotene, lycopene, and lutein and cardiovascular disease risk reduction
- New data on vitamin A deficiency in *Global Perspective*
- Newest Daily Values incorporated into food sources of vitamin D (Figure 12-11)
- Streamlined discussion of vitamin D needs, toxicity, and concerns
- Latest Daily Values for vitamin E included in food sources (Figure 12-16)
- Discussion of latest vitamin E research related to cancer added
- Vitamin K food sources revised to reflect newest Daily Values (Figure 12-20)
- *Case Study* updated to reflect newly released Daily Values

Chapter 13, *The Water-Soluble Vitamins*

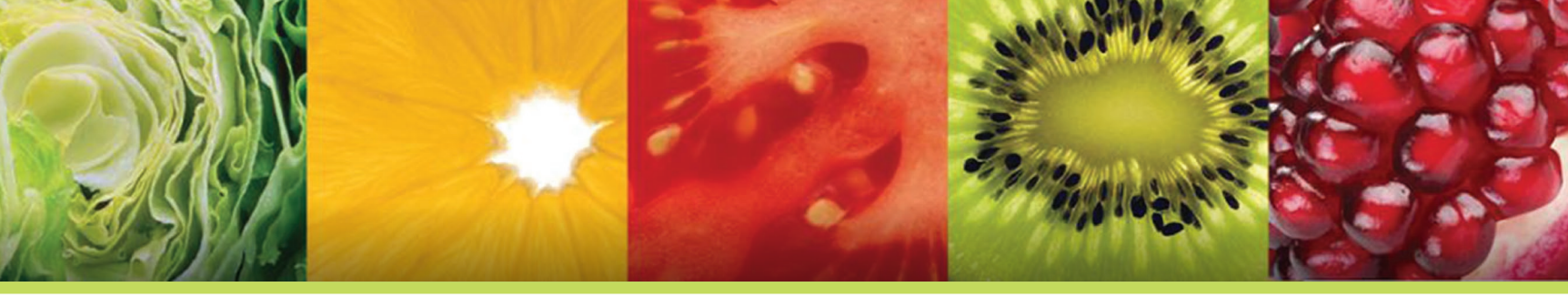
- Water-soluble vitamin intakes, prominent food sources, and the prevalence of inadequate intake statistics updated
- Expanded vitamin functions to address 1 carbon metabolism (Figure 13-1)
- New section on B-vitamins and epigenetics
- Streamlined discussion on thiamin discovery, transketolase coenzyme function, and deficiency
- Thiamin food sources updated to reflect latest Daily Values (Figure 13-6)
- Newest Daily Values incorporated into food sources of riboflavin (Figure 13-7)
- Updated food sources of niacin (Figure 13-9) to reflect latest Daily Values
- Refined discussion of niacin absorption, transport, storage, and excretion
- Extensive update of pharmacologic use of niacin
- Latest Daily Values for pantothenic acid included in food sources (Figure 13-12)
- Figure depicting food sources of biotin updated with most recent Daily Values (Figure 13-13)
- Expanded discussion of risks associated with high homocysteine blood concentrations
- Vitamin B-6 food sources incorporate latest Daily Values (Figure 13-14)
- Updated information on the pharmacologic use of vitamin B-6
- Refined presentation of folate in foods and updated with latest Daily Values (Figure 13-16)
- New *Culinary Perspective* on beans, lentils, and dried peas
- Food sources of vitamin B-12 revised to reference recently released Daily Values (Figure 13-19)
- Extensive revision of choline functions
- Streamlined discussion of vitamin C sources and updated to newest Daily Values (Figure 13-23)
- Enhanced presentation of vitamin C's function as an antioxidant
- New case studies of recent scurvy cases incorporated
- Condensed material by excluding discussion of vitamin-like compounds

Chapter 14, *Water and Major Minerals*

- Enhanced figure to feature water's role in many processes in the body (Figure 14-1)
- Streamlined description of functions of water
- Refined sources of water discussion
- Updated presentation of dehydration and water intoxication
- Focused presentation of overall mineral deficiencies on Dietary Guidelines for Americans
- Latest statistics on major mineral intakes, prominent food sources, and the prevalence of inadequate intake included
- Food sources of sodium revised to reference recently released Daily Values (Figure 14-12)
- Streamlined presentation of excess sodium intake and Upper Level to maximize clarity
- New *Culinary Perspective* on specialty and sea salt
- Updated food sources of potassium to include newest Daily Value (Figure 14-14)
- Refined presentation of hypertension risk factors
- Updated food sources of calcium (Figure 14-15) to reflect latest Daily Value
- Reorganized calcium supplements discussion to enhance understanding
- Streamlined presentation of factors increasing osteoporosis risk (Table 14-11)
- Latest Daily Values for phosphorus included in food sources (Figure 14-26)
- Magnesium food sources incorporate most recently released Daily Values (Figure 14-27)

Chapter 15, *Trace Minerals*

- Food sources of zinc revised to reference recently released Daily Values (Figure 15-18)
- Figure depicting food sources of copper updated with most recent Daily Values (Figure 15-11)
- Manganese food sources incorporate latest Daily Values (Figure 15-13)



- Updated food sources of selenium to include newest Daily Value (Figure 15-17)
- Latest fluoridated water statistics for the U.S. added (Figure 15-20)
- Enhanced *Take Action* focusing on fluoridation
- Refined *Clinical Perspective* on nutrients, diet, and cancer to reflect newest research and recommendations
- Latest statistics on cancer deaths incorporated (Figure 15-21)

Chapter 16, *Nutritional Aspects of Pregnancy and Breastfeeding*

- *Expert Perspective from the Field* updated to include fortification of masa corn meal
- Updated pregnancy and malnutrition statistics
- Smoking during pregnancy and breastfeeding expanded to include nicotine from cigarettes, electronic cigarettes, and patches
- Dietary intake of breastfeeding women with regard to potential allergens updated
- Added advice from the CDC for breastfeeding by women with HIV

Chapter 17, *Nutrition during the Growing Years*

- Updated guidance on cholesterol screening for children
- New section on potassium needs during the growing years
- New breastfeeding statistics added
- Updated table describing advantages to infants provided by human milk (Table 17-2)
- Expanded discussion of physical abilities indicating infants' readiness for solid foods
- Complete overhaul of Figure 17-5 describing the latest infant feeding guidelines from the American Academy of Pediatrics
- American Academy of Pediatrics whole diet approach and children's diet incorporated
- Added American Academy of Pediatrics guidelines for parents of toddlers
- New school wellness policy legislation reviewed
- Hyperactivity section updated

Chapter 18, *Nutrition during the Adult Years*

- Updated statistics and figure (Figure 18-1) summarizing life expectancy
- Table summarizing current hypotheses about the causes of aging (Table 18-1) updated and enhanced
- Potassium as a nutrient of concern for adults added
- Role of increased protein intake as potential strategy for reducing risk of sarcopenia introduced
- Current chronic disease prevalence rates incorporated
- Revised *Clinical Perspective* to reflect newest categorization of complementary and alternative health approaches
- Streamlined table summarizing popular herbal remedies (Table 18-6)

Acknowledgments

We offer a hearty and profound thank you to the many individuals who have supported and guided us along the way.

To our loved ones: Without your patience, understanding, assistance, and encouragement, this work would not have been possible.

To our wonderful students—past, present, and future: The lessons you have taught us over the years have enlightened us and sustained our desire to provide newer, better opportunities to help you successfully launch your careers and promote healthful lifelong living. Thank you in particular to the students who have used SmartBook®, as your feedback was instrumental in the revisions for this edition.

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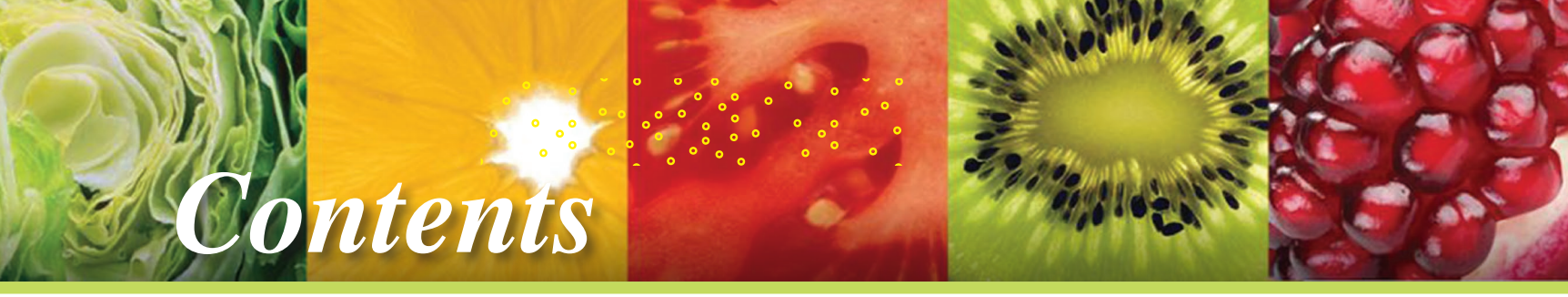
To Your Health!

Carol Byrd-Bredbenner
Gaile Moe
Jacqueline Berning
Danita Kelley



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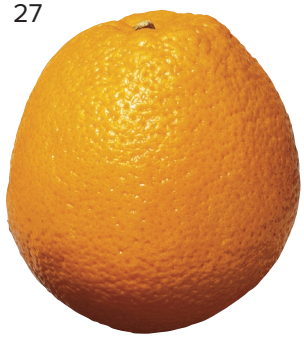

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A nutritious, delicious, and varied diet is key to good health and longevity. To learn more, carefully study this text and visit **nutrition.gov.**

1 The Science of Nutrition

Learning Objectives

After studying this chapter, you will be able to

1. Define the terms *nutrition, carbohydrates, proteins, lipids* (fats and oils), *vitamins, minerals, water,* and *calories*.
2. Use the physiological fuel values of energy-yielding nutrients to determine the total energy content (calories) in a food or diet.
3. Describe the major characteristics of the North American diet and the food behaviors that often need improvement.
4. Describe the factors that affect our food choices.
5. Discuss the components and limitations of nutritional assessment.
6. List the attributes of lifestyles that are consistent with *Healthy People 2020* goals and those that contribute to the leading causes of death in North America.
7. Describe the role of genetics in the development of nutrition-related diseases.
8. Explain how the scientific method is used in developing hypotheses and theories in the field of nutrition.
9. Identify reliable sources of nutrition information.

Chapter Outline

IN OUR LIFETIMES, WE WILL eat about 60 tons of food served at 70,000 meals and countless snacks. Research over the last 50 years has shown that the foods we eat have a profound impact on our health and longevity. A healthy diet—especially one rich in fruits and vegetables—coupled with frequent exercise can prevent and treat many age-related diseases.[1] In contrast, eating a poor diet and getting too little exercise are **risk factors** for many common life-threatening, chronic diseases, such as cardiovascular (heart) disease, diabetes, and certain forms of cancer.[2,3] Another diet-related problem, drinking too much alcohol, can impair nutritional status and is associated with liver disease, some forms of cancer, accidents, and suicides. As you can see in Figure 1-1, diet plays a role in the development of most of the leading causes of death in the U.S. The combination of poor diet and too little physical activity contributes to well over half of these deaths.[3,4]

We live longer than our ancestors did, so preventing age-related diseases is more important now than ever before. Today, many people want to know more about how nutritious dietary choices can bring the goal of a long, healthy life within reach.[5] They may wonder what the best dietary choices are, how nutrients contribute to health, or if multivitamin and mineral supplements are needed. How can people know if they are eating too much saturated fat, *trans* fat, or cholesterol? Why are carbohydrates important? Is it possible to get too much protein?

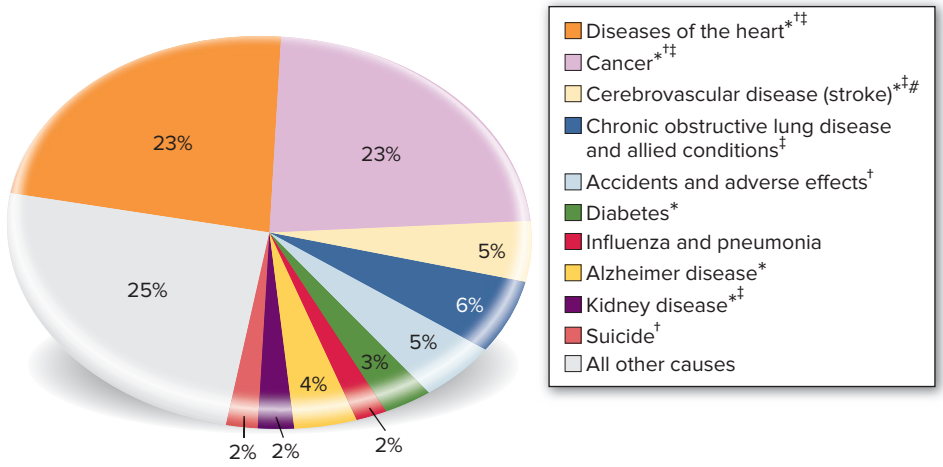

Figure 1-1 Leading causes of death in the U.S. The major health problems in North America are largely caused by a poor diet, excessive energy intake, and not enough physical activity.

Source: From Centers for Disease Control and Prevention, National vital Statistics Report, Canadian Statistics are quite similar.

* Causes of death in which diet plays a part
† Causes of death in which excessive alcohol consumption plays a part
‡ Causes of death in which tobacco use plays a part
# Diseases of the heart and cerebrovascular disease are included in the more global term *cardiovascular disease.*

Bold terms in the book are defined in the Glossary. Bold terms also are defined in the text and/or nearby when first presented.

Is the food supply safe to eat? Would a vegetarian diet lead to better health? This book, beginning with this chapter, will help you build the nutrition knowledge base needed to answer these questions (and many more!) and apply this knowledge to safeguard your health, as well as the health of others.

As you begin your study of nutrition, keep in mind that this field draws heavily on chemistry, biology, and other sciences. For the greatest understanding of nutrition principles, you may want to review human physiology (Appendix A), basic chemistry concepts (Appendix B), and the metric system (Appendix H).

1.1 Nutrition Overview

The American Medical Association defines **nutrition** as the "science of food; the nutrients and the substances therein; their action, interaction, and balance in relation to health and disease; and the process by which the organism (e.g., human body) ingests, digests, absorbs, transports, utilizes, and excretes food substances." Food provides the nutrients needed to fuel, build, and maintain all body cells.

Nutrients

You probably are already familiar with the terms *carbohydrates, lipids* (fats and oils), *proteins, vitamins,* and *minerals* (Table 1-1). These, plus water, make up the 6 classes of nutrients in food. **Nutrients** are substances essential for health that the body cannot make or that it makes in quantities too small to support health.

To be considered an essential nutrient, a substance must have these characteristics:

- Have a specific biological function
- Cause a decline in normal human biological function, such as the normal functions of the blood cells or nervous system, if removed from the diet
- Restore normal human biological function that was impaired by its absence if returned to the diet before permanent damage occurs

Table 1-1 Nutrients in the Human Diet*

Energy-Yielding Nutrients					
Carbohydrate	**Lipids (Fats and Oils)**	**Protein (Amino Acids)**			
Glucose (or a carbohydrate that yields glucose)	Linoleic acid (omega-6) Alpha-linolenic acid (omega-3)	Histidine Isoleucine Leucine	Lysine Methionine Phenylalanine	Threonine Tryptophan Valine	
Non-Energy-Yielding Nutrients					
Vitamins		**Minerals**			
Water-Soluble	**Fat-Soluble**	**Major**	**Trace**	**Questionable**	**Water**
Thiamin	A	Calcium	Chromium	Arsenic	Water
Riboflavin	D	Chloride	Copper	Boron	
Niacin	E	Magnesium	Fluoride	Nickel	
Pantothenic acid	K	Phosphorus	Iodide	Silicon	
Biotin		Potassium	Iron	Vanadium	
B-6		Sodium	Manganese		
B-12		Sulfur	Molybdenum		
Folate			Selenium		
C			Zinc		

*This table includes nutrients that the *current Dietary Reference Intakes* and related publications list for humans. There is some disagreement about whether the questionable minerals and certain other minerals not listed in the table are required for human health. Fiber could be added to the list of required substances, but it is not a nutrient (see Chapter 5). The vitamin-like compound choline plays vital roles in the body but is not listed under the vitamin category at this time. Alcohol is a source of energy, but it is not a nutrient.

Nutrients can be assigned to 3 functional categories (Table 1-2):

1. Those that primarily provide energy (typically expressed in kilocalories [kcal])
2. Those that are important for growth and development (and later maintenance)
3. Those that regulate body processes and keep body functions running smoothly

Some overlap exists among these categories. The energy-yielding nutrients and water make up a major portion of most foods.[6]

Because carbohydrates, proteins, lipids, and water are needed in large amounts, they are called **macronutrients**. In contrast, vitamins and minerals are needed in such small amounts in the diet that they are called **micronutrients**. Let's now look more closely at the classes of nutrients.

Table 1-2 Functional Categories of Nutrients

Provide Energy	Promote Growth and Development	Regulate Body Processes
Most carbohydrates	Proteins	Proteins
Proteins	Lipids	Some lipids
Most lipids (fats and oils)	Some vitamins	Some vitamins
	Some minerals	Some minerals
	Water	Water

Alcoholic beverages are rich in energy (calories), but alcohol is not a nutrient.

Many foods are rich sources of the nutrients we recognize today as essential for health.

Carbohydrates

Carbohydrates are composed mainly of the **elements** carbon, hydrogen, and oxygen. Fruits, vegetables, grains, beans, and sugars are the primary dietary sources of carbohydrate. The main types of carbohydrates are simple and complex. Small carbohydrate structures are called sugars or simple carbohydrates—table sugar (sucrose) and blood sugar (glucose) are examples. Some sugars, such as glucose, can chemically bond together to form large carbohydrates, called polysaccharides or complex carbohydrates (Fig. 1-2). Examples of complex carbohydrates include the starch in grains and the glycogen stored in our muscles. Fiber, another type of complex carbohydrate, forms the structure of plants.

Glucose, which comes from simple carbohydrates and starch, is a major source of energy in most cells. It and most other carbohydrates provide an average of 4 calories per gram (kcal/g).[7] (Fiber provides little energy because it cannot be broken down by digestive processes.) When too little carbohydrate is eaten to supply sufficient glucose, the body is forced to make glucose from proteins. (Chapter 5 focuses on carbohydrates.)

Lipids

Like carbohydrates, lipids (e.g., fats, oils, and cholesterol) are **compounds** composed mostly of the elements carbon, hydrogen, and oxygen (Fig. 1-3). Note that the term *fats* refers to lipids that are solid at room temperature, whereas oils are those that are liquid

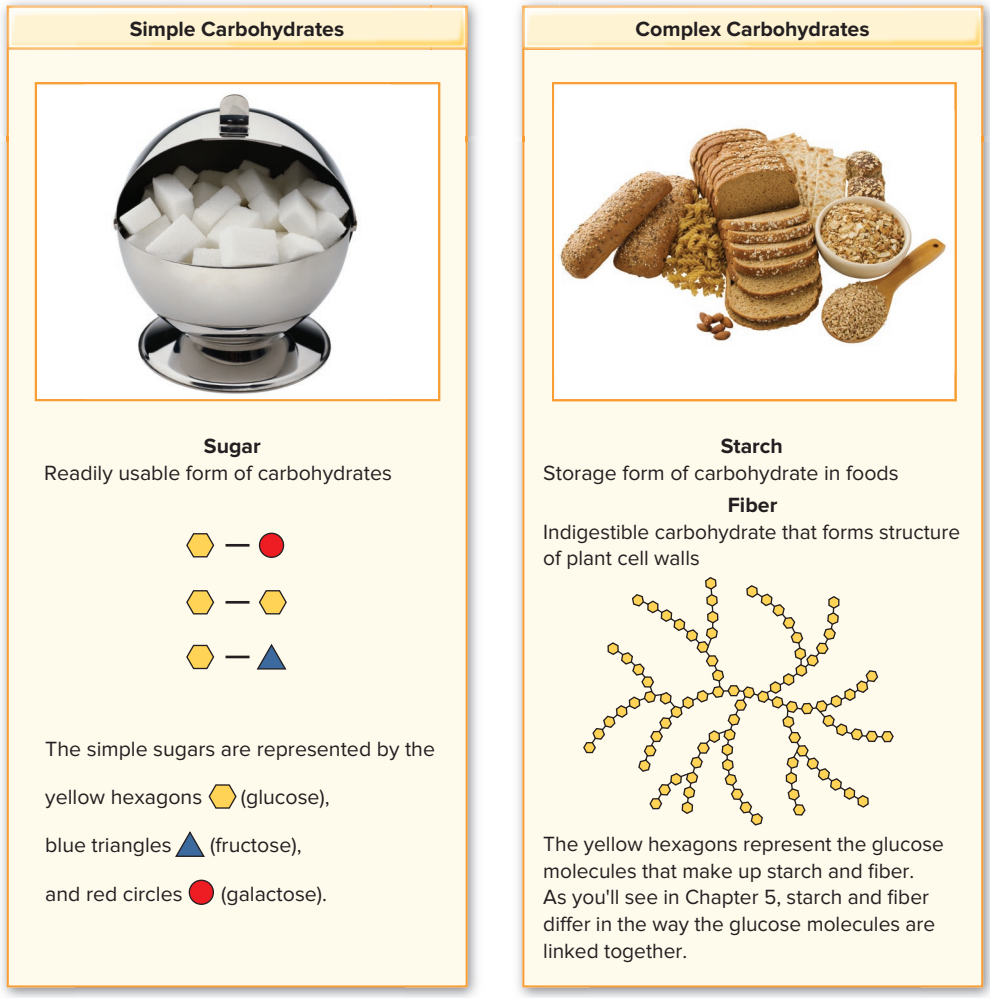

Figure 1-2 Two views of carbohydrates—dietary and chemical.

macronutrient Nutrient needed in gram quantities in the diet.

micronutrient Nutrient needed in milligram or microgram quantities in a diet.

element Substance that cannot be separated into simpler substances by chemical processes. Common elements in nutrition include carbon, oxygen, hydrogen, nitrogen, calcium, phosphorus, and iron.

at room temperature. Lipids yield more energy per gram than carbohydrates—on average, 9 calories per gram. (See Chapter 9 for details about the high energy yield of lipids.) Lipids are insoluble in water but can dissolve in certain organic solvents (e.g., ether and benzene).

The lipid type called a **triglyceride** is the major form of fat in foods and a key energy source for the body. Triglycerides also are the major form of energy stored in the body. They are composed of 3 fatty acids attached to a glycerol **molecule**. Fatty acids are long chains of carbon flanked by hydrogen with an acid group attached to the end opposite glycerol.

Most lipids can be separated into 2 basic types—saturated and unsaturated—based on the chemical structure of their dominant fatty acids. This difference helps determine whether a lipid is solid or liquid at room temperature, as well as its effect on health. Although almost all foods contain a variety of saturated and unsaturated fatty acids, plant oils tend to contain mostly unsaturated fatty acids, which make them liquid at room temperature. Many animal fats are rich in saturated fatty acids, which make them solid at room temperature. Unsaturated fats tend to be healthier than saturated fats—saturated fat raises blood cholesterol, which can clog arteries and eventually lead to cardiovascular disease.

Two specific unsaturated fatty acids—linoleic acid and alpha-linolenic acid—are essential nutrients. They must be supplied by our diets. These essential fatty acids have many roles, including being structural components of cell membranes and helping regulate blood pressure and nerve transmissions. A few tablespoons of vegetable oil daily and eating fish at least twice weekly supply sufficient amounts of essential fatty acids.[7]

Some foods also contain *trans* fatty acids—unsaturated fats that have been processed to change their structure from the more typical *cis* form to the *trans* form (see Chapter 6). These are found primarily in deep-fried foods (e.g., donuts, french fries), baked snack foods (e.g., cookies, crackers), and solid fats (e.g., stick margarine, shortening). Large amounts of *trans* fats in the diet pose health risks, so, like saturated fat, their intake should be minimized.[7] (Chapter 6 focuses on lipids.)

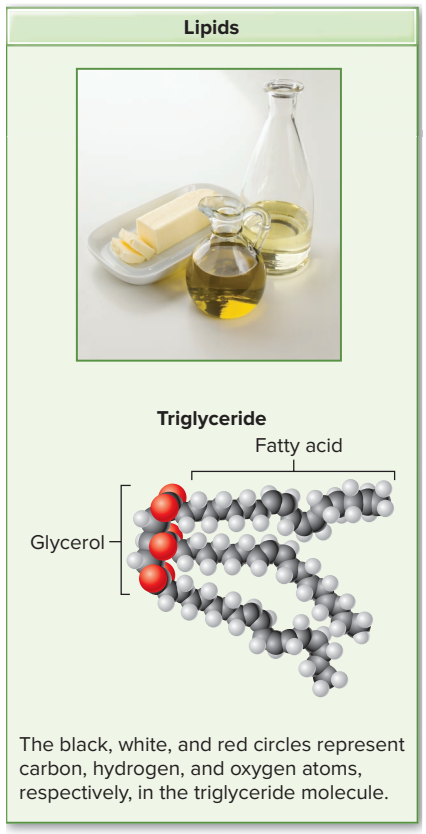

Figure 1-3 Dietary and chemical views of lipids.

lipids: ©Tetra Images/Getty Images RF

Proteins

Proteins, like carbohydrates and fats, are composed of the elements carbon, oxygen, and hydrogen (Fig. 1-4). Proteins also contain another element—nitrogen. Proteins are the main structural material in the body. For example, they are a major part of bone and muscle; they also are important components in blood, cell membranes, **enzymes**, and immune factors.[7] Proteins can provide energy for the body—on average, 4 calories per gram; however, the body typically uses little protein to meet its daily energy needs.

Proteins form when amino acids bond together. Twenty common amino acids are found in food; 9 of these are essential nutrients for adults, and 1 additional amino acid is essential for infants. (Chapter 7 focuses on proteins.)

Vitamins

Vitamins have a wide variety of chemical structures and can contain the elements carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur, and others. The main function of vitamins is to enable many **chemical reactions** to occur in the body. Some of these reactions help release the energy trapped in carbohydrates, lipids, and proteins. Vitamins themselves provide no usable energy for the body.

The 13 vitamins are divided into 2 groups. Fat-soluble vitamins (A, D, E, and K) dissolve in fat. Vitamin C and the B-vitamins (thiamin, riboflavin, niacin, vitamin B-6, pantothenic acid, biotin, folate, and vitamin B-12) are water-soluble vitamins. The vitamin groups often act quite differently. For example, cooking is more likely to destroy water-soluble vitamins than fat-soluble vitamins. Water-soluble vitamins are excreted from the body much more readily than fat-soluble vitamins. As a result, fat-soluble vitamins, especially vitamin A, are much more likely to accumulate in excessive amounts in the body, which then can cause toxicity. (Vitamins are the focus of Part 4.)

atom Smallest unit of an element that still has all the properties of the element. An atom contains protons, neutrons, and electrons.

compound Atoms of 2 or more elements bonded together in specific proportions.

molecule Atoms linked (bonded) together; the smallest part of a compound that still has all the properties of a compound.

enzyme Compound that speeds the rate of a chemical process but is not altered by the process. Almost all enzymes are proteins (some are made of nucleic acids).

chemical reaction Interaction between 2 or more chemicals that changes both chemicals.

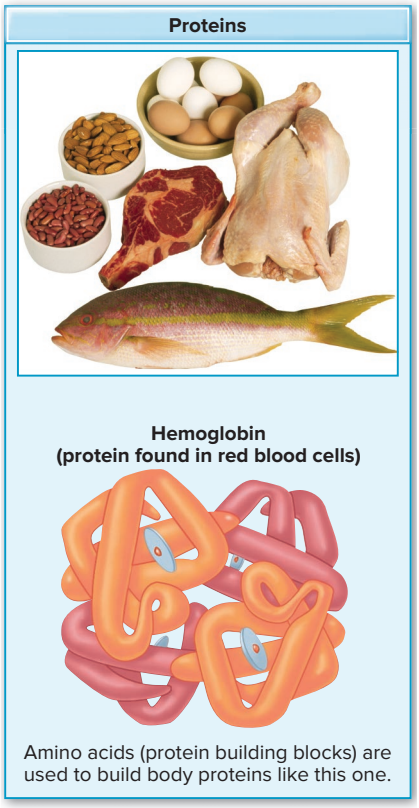

Figure 1-4 Dietary and chemical views of proteins.

proteins: ©Comstock/Getty Images RF

Minerals

The nutrients discussed so far are all complex organic compounds, whereas minerals are structurally very simple, inorganic substances. The chemical structure of an **organic compound** contains carbon atoms bonded to hydrogen atoms, whereas an **inorganic substance** generally does not. In this case, the term *organic* is not related to the farming practices that produce organic foods (these are described in Chapter 3).

Minerals typically function in the body as groups of one or more of the same atoms (e.g., sodium or potassium) or as parts of mineral combinations, such as the calcium- and phosphorus-containing compound called hydroxyapatite, found in bones. Because they are elements, minerals are not destroyed during cooking. (However, they can leak into cooking water and get discarded if that water is not consumed.) Minerals yield no energy for the body but are required for normal body function. For instance, minerals play key roles in the nervous system, the skeletal system, and water balance.

Minerals are divided into 2 groups: major minerals and trace minerals. Major minerals are needed daily in gram amounts. Sodium, potassium, chloride, calcium, and phosphorus are examples of major minerals. Trace minerals are those that we need in amounts of less than 100 milligrams (mg) daily. Examples of trace minerals are iron, zinc, copper, and selenium. (Minerals are the focus of Part 4.)

Water

Water is the 6th class of nutrients. Like minerals, water also is inorganic. Although sometimes overlooked as a nutrient, water is the nutrient needed in the largest quantity. Water (H_2O) has numerous vital functions in the body. It acts as a solvent and lubricant and is a medium for transporting nutrients to cells. It also helps regulate body temperature. Beverages, as well as many foods, supply water. The body even makes some water as a by-product of **metabolism**. (Water is examined in detail in Part 4.)

Tomatoes contain the phytochemical lycopene; thus, they can be called a functional food.

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Phytochemicals and Zoochemicals

Phytochemicals (plant components in fruits, vegetables, legumes, and whole grains) and **zoochemicals** (components in animals) are physiologically active compounds. They are not considered essential nutrients in the diet. Still, many of these substances provide significant health benefits.[8] For instance, numerous studies show reduced cancer risk among people who regularly consume fruits and vegetables. Researchers surmise that some phytochemicals in fruits and vegetables block the development of cancer (see Part 4).[9] Some phytochemicals and zoochemicals also have been linked to a reduced risk of cardiovascular disease.[10]

It will likely take many years for scientists to unravel the important effects of the many different phytochemicals and zoochemicals in foods. Multivitamin and mineral supplements

organic compound Substance that contains carbon atoms bonded to hydrogen atoms in the chemical structure.

inorganic substance Substance lacking carbon atoms bonded to hydrogen atoms in the chemical structure.

metabolism Chemical processes in the body that provide energy in useful forms and sustain vital activities.

phytochemical Physiologically active compound in plants that may provide health benefits.

zoochemical Physiologically active compounds in foods of animal origin that may provide health benefits.

Expert Perspective from the Field

Functional Foods

Foods rich in phytochemicals (chemicals from plants) and zoochemicals (chemicals from foods of animal origin) are sometimes referred to as functional foods. A functional food provides health benefits beyond those supplied by the traditional nutrients it contains—the food offers additional components that may decrease disease risk and/or promote optimal health. According to Dr. Clare Hasler-Lewis,* **functional foods** fall into 4 categories shown in the table.[8]

The phytochemicals and zoochemicals that are present naturally in unmodified whole foods like fruits and vegetables are thought to provide many health benefits (see Table 1-3). Foods modified by adding nutrients, phytochemicals, zoochemicals, or herbs (see Chapter 18) also may provide health benefits. For instance, orange juice fortified with calcium may help prevent osteoporosis. Medical foods are designed to help enhance the management of health conditions. An example is phenylalanine-restricted formula fed to infants born with the inborn error of metabolism condition called phenylketonuria (PKU) (see Chapter 9). This formula helps them develop normally. Dr. Hasler-Lewis indicated that the array of modified foods, medical foods, and special dietary use foods is expanding rapidly. An important trend in the food industry is the addition of nutrients, phytochemicals, and other components in hopes of boosting the healthfulness of the food supply.

**Clare M. Hasler-Lewis, Ph.D., MBA, is an international authority on functional foods. She is the founding executive director of the Robert Mondavi Institute for Wine and Food Science at the University of California, Davis, and serves as the university's primary liaison to the wine and food industries. Dr. Hasler-Lewis also was the founding director of the Functional Foods for Health Program at the University of Illinois.*

Four Functional Food Categories[8]

Conventional Foods: Unmodified Whole Foods

Fruits, Vegetables, Herbs, Spices, Nuts, Dairy products, Fish

Modified Foods: Fortified, Enriched, or Enhanced Foods

Calcium-fortified orange juice
Omega-3-enriched bread
Breakfast bars enhanced with ginkgo biloba
Cheese made with plant sterols

Medical Foods: Food, Formula, or Supplement Used under Medical Supervision to Manage a Health Condition

Phenylalanine-free formulas for phenylketonuria (PKU)
Limbrel® for osteoarthritis
Axona® for Alzheimer disease
VSL#3® for ulcerative colitis
GlycemX™ 360 for diabetes management

Special Dietary Use Foods: Foods That Help Meet a Special Dietary Need

Infant formula for infants
Lactose-free foods for lactose intolerance
Sugar-free foods for weight loss
Gluten-free foods for celiac disease

Source:Brown AC, Hasler C., "Position of the American Dietetic Association: Functional Foods," *Journal of of the American Dietetic Association*, vol 109, issue 4, 2009, p. 735.

currently contain few or none of these beneficial chemicals. Thus, nutrition and health experts suggest that a diet rich in fruits, vegetables, legumes, and whole-grain breads and cereals is the most reliable way to obtain the potential benefits of phytochemicals.[11] In addition, foods of animal origin, such as fatty fish, can provide the beneficial zoochemical omega-3 fatty acids (see Chapter 6), and fermented dairy products provide probiotics (see Chapter 4). Table 1-3 lists some phytochemicals and zoochemicals under study, with their common food sources.

To learn more about bioactive compounds in foods, visit www.sigma-aldrich.com/life-science/nutrition-research/learning-center/bioactive-nutrient-explorer.html and nutrition.ucdavis.edu/content/infosheets/fact-pro-phytochemical-2016.pdf.