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Essentials of Nutrition and Diet Therapy

12TH EDITION

ELEANOR D. SCHLENKER
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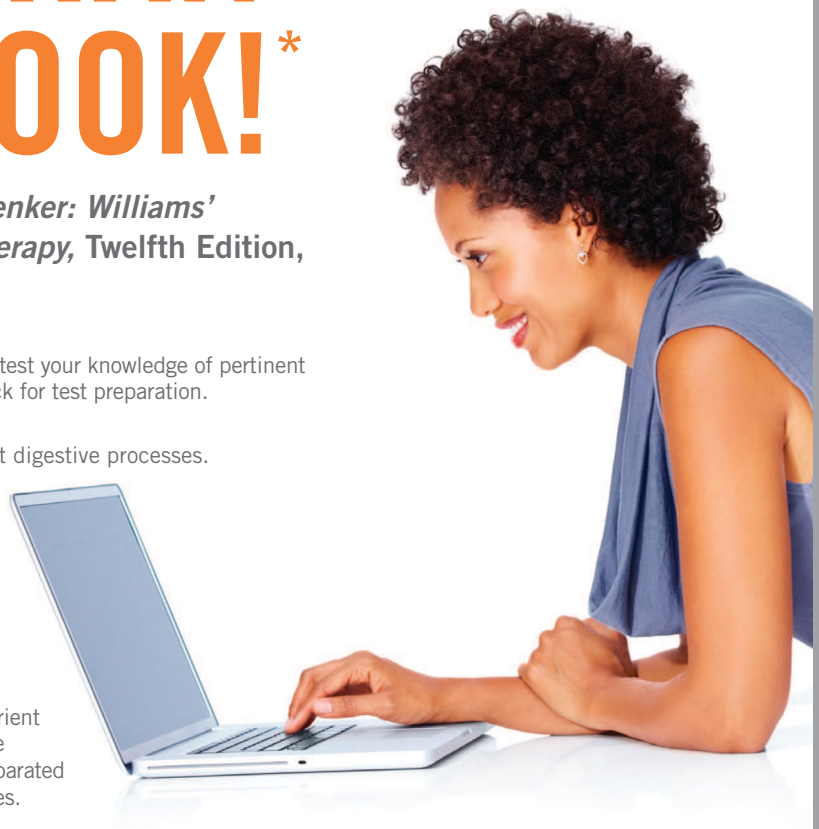

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Williams'

Essentials of Nutrition and Diet Therapy

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12th EDITION

Williams' Essentials of Nutrition and Diet Therapy

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WILLIAMS' ESSENTIALS OF NUTRITION AND DIET THERAPY, TWELFTH EDITION

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We continue to be indebted to Sue Rodwell Williams who created the first eight editions of this text, and set the standard that we strive to follow.

The Authors

To my parents, Harold and Nora, who taught me to appreciate the opportunity to learn.

Eleanor D. Schlenker

To my mom, Helen, who taught me knowledge is power and to my many mentors who have taught me how to harness the power of knowledge.

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PREFACE

Through eleven highly successful editions, this nutrition textbook has presented a sound approach to student learning and clinical practice in the health professions. It provides both a strong research base and a person-centered approach to the study and application of nutrition in human health. We have appreciated the suggestions and positive reception of this text by users in colleges, community colleges, and clinical settings throughout the United States and in other parts of the world.

New discoveries in nutrition science and its application to human health provide the foundation for the rapidly evolving protocols in public health and clinical care. Evidence-based practice rather than dependence on custom or prior learning is the new standard for decision-making. The expanding science base in biology, biotechnology, and health is leading to new arenas of practice such as nanotechnology, nutrigenomics, and functional foods. Recent changes in the U.S. population are creating new challenges for the health professional. Government agencies have noted that for the first time in history, our population cannot be considered to be "healthy," based on the prevalence of obesity and growing chronic disease observed in both youth and adults. Our population is also becoming more diverse in culture and ethnicity. These observations carry implications for future health professionals and their formal preparation for working in public health, community, clinical, or industry settings. The health professionals of the future must deal creatively with the realities of chronic disease. They must develop a framework of understanding of the needs of diverse populations and food patterns that differ from their own. The worldwide epidemic of obesity, diabetes, and related chronic disease, fueling the rise in health care costs, is drawing attention to new methods for delivery of health care and disease prevention strategies and the importance of both appropriate food and physical activity patterns in developing a healthy lifestyle. Public interest and concern for nutrition and health are increasing, although consumers often depend on less reliable sources of information. New technology and the Internet offer unlimited opportunities for meaningful nutrition and health intervention programs, despite the appearance of false advertising and misleading health claims. Nutrition has become prominent in the marketplace promoting functional foods and expanding product lines. Such changes present both opportunities and challenges for the future health professional.

This new edition reflects these far-reaching changes. We continue to be guided by a commitment to sound nutrition principles rooted in basic science and their application to human health and well-being. We have built on previous editions to produce this new book—updated and rewritten, with our new design and format—to meet the changing needs of students, faculty, and practitioners in the health professions.

NEW TO THIS EDITION

To accommodate the demands of a rapidly emerging science and an increasingly diverse society, the entire text has been updated. Changes and additions based on input from many teachers, students, and clinicians have been incorporated to increase its usefulness.

Chapter Changes

With the retirement of Dr. Sue Rodwell Williams, the founder and primary author of the first eight editions of this textbook, we continue to share responsibility for the preparation of this new edition. Part 1, *Introduction to Human Nutrition,* provides the foundation in nutrition science and we apply these principles to human nutrition needs and food selection in Part 2, *Community Nutrition and the Life Cycle.* Part 3, *Introduction to Clinical Nutrition,* describes the nutrition care process for nutritional intervention and the application of medical nutrition therapy in the treatment of both acute and chronic diseases and conditions.

We welcome both new and continuing contributors to this edition. Kary Woodruff prepared Chapter 11, "Nutrition During Pregnancy and Lactation," Chapter 12, "Nutrition for Normal Growth and Development, and Chapter 14, "Nutrition and Physical Fitness." Pamela Charney revised Chapter 19, "Nutrition Support: Enteral and Parenteral Nutrition." Dr. Dorothy Chen-Maynard completed Chapter 20, "Gastrointestinal Diseases," and Dr. Adriana Campa contributed Chapter 24, "Acquired Immunodeficiency Syndrome (AIDS)."

New material has been incorporated throughout this edition, reflecting recent research findings and clinical treatment therapies. Examples include new roles for traditional nutrients such as vitamin D, updates on the transmission and treatment of acquired immunodeficiency syndrome (AIDS), and recent attention to protein needs and effective utilization. Health promotion with strategies for implementation is a recurring theme throughout the text, and students are encouraged to look for the *Health Promotion* heading in each chapter for special information to assist with nutrition education in a variety of settings. New research pointing to the application and effectiveness of text messaging and other technologies in support of nutrition education and medical nutrition therapy is reviewed. Full coverage of the U.S. Department of Agriculture and U.S. Department of Health and Human Services health initiatives including MyPlate, the Dietary Guidelines for Americans, and Healthy People 2020 includes goals, practice standards, and application and usefulness to health promotion. We provide an overview of the New Nutrition Label and its helpfulness to consumers. To support future work with the growing elderly population, the MyPlate for Older Adults, developed by Tufts University and the American Association of Retired Persons Foundation is presented in the chapter on nutritional needs for adults. Simple screening protocols for identifying potential malnutrition in older adults will be helpful for students when entering their clinical practice.

The chapters on energy balance and obesity provide readers with a comprehensive review of this public health problem including proposed contributing factors such as sleep deprivation and the intestinal microbiome. Interventions to stem the advance of the obesity epidemic, including new regulations for school breakfast and lunch that limit kilocalories and emphasize fruit, vegetables and whole grains, and current activity recommendations for children are presented. The chapter on nutrition and physical performance includes emerging research pertaining to protein and fluid needs, dietary supplements, and the benefits of exercise on risk factors for cardiovascular disease and diabetes. A public health approach to nutrition and well-being provides a framework for developing and marketing community nutrition and health intervention programs with attention to needs assessment, implementation, and evaluation. Throughout the text students are reminded of factors that contribute to food insecurity among all age and population groups and government agencies and programs that can help individuals and families meet their food needs.

Feature boxes addressing contemporary issues in nutrition and health have been updated. Each chapter includes an example of *Evidence-Based Practice*, guiding students through the critical thought process and reinforcing this concept for future use in the practice

setting. The *Complementary and Alternative Medicine (CAM)* boxes—found in all chapters in Part 3—review and evaluate new therapies relevant to chapter topics. *Focus on Culture* boxes introduce students to the concept of cultural competence and the nutritional deficiencies, health problems, and appropriate interventions pertinent to various cultural, ethnic, racial, and age-groups. *Focus on Food Safety* boxes alert readers to food safety issues pertaining to a particular nutrient, medical condition, or segment of the population. *Perspectives in Practice* boxes provide practical elements for nutrition education that students will find helpful in their future roles. Tools available for download from government or other reputable public sites are noted. "Websites of Interest" connect students with accurate and objective Internet resources, useful in finding answers to patient inquiries. "Further Readings and Resources" from the research and professional literature enable further inquiry into a topic of interest.

PERSONAL APPROACH

The person-centered approach that has been a hallmark of the Williams' text over the years continues in this edition. The authors and contributors write in a personal style using materials and examples from personal research and clinical experience. Scientific knowledge is presented in human terms as a tool to develop practical solutions to individual problems.

Illustrations and Design

Numerous illustrations, anatomic figures, graphic line drawings, and photographs, most in full color, enhance the overall design and help students better understand the concepts and clinical practices presented.

Enhanced Readability and Student Interest

Continuing attention has been given to enhancing readability and enlivening the text stylistically with use of boxes, illustrations, and recurring themes that capture student interest and assist in comprehension. New material has been added, and remaining sections have been rewritten. Recent advances in basic and clinical science are explained and applied. Issues of public and professional controversy pertinent to students' future practice are examined.

Learning Aids Within the Text

This twelfth edition continues to include many aids that assist student learning.

Chapter Openers

To alert students to the content of each chapter and draw them into its study, each chapter opens with a preview of chapter topics and their relevance to professional practice. An outline of the major chapter headings is also included on this page.

Key Terms

Key terms important to the student's understanding and application of the chapter content are presented in two steps. First, they are identified in blue type in the body of the text. Then, these terms are grouped and defined in boxes in the lower corners of the pages close to their mention. This dual-level approach to vocabulary development greatly improves the overall study and usefulness of the text.

Pedagogy Boxes

Perspectives in Practice, Focus on Culture, Evidence-Based Practice, Complementary and Alternative Medicine (CAM), and Focus on Food Safety: These special features throughout the text introduce supplemental material, apply subject matter to evidence-based decision-making, introduce chapter-related issues or controversies, present a deeper look at chapter topics, or describe a practical application of a nutrition concept. These interesting and motivating studies help the student comprehend the importance of scientific thinking and develop sound judgment and openness to varied points of view.

Case Studies

In Parts 2 and 3 realistic case studies provide opportunities for problem solving, relating the information learned to practical situations in nutrition care. Each chapter contains at least one case with questions for analysis, decision-making, and intervention. These case studies help students apply principles of community nutrition and medical nutrition therapy to individuals and groups they will meet in their clinical assignments.

Chapter Summaries

To assist students in drawing the chapter material together as a whole, each chapter concludes with a summary of the key concepts presented and their significance or application. The student can then return to any part of the chapter for repeated study and clarification as needed.

Review Questions

To help students think critically about key components of the chapter and how they relate to community and patient needs or problems, review questions conclude each chapter. Questions go beyond the simple review of facts, requiring problem-solving and critical thinking. Review questions may require the student to seek information or perspective beyond what is found in the text using the scientific literature, the popular literature, community meal or public health programs, nutrition labeling, or population data from government sources.

Chapter References

A strength of this text is the documentation of the topics presented, drawn from a wide selection of pertinent journals. To provide immediate access to all references cited in the chapter text, a full list is given at the end of each chapter rather than collected at the end of the book. Special attention has been directed toward selection of references published within the last 4 to 7 years.

Further Readings And Resources

In addition to referenced material from the text, an annotated list of suggestions for further reading is provided at the end of each chapter. These selections extend or apply the text material according to student needs or special interests. The annotations improve their usefulness by identifying the pertinent topics of the reference. Also included is a list of reliable websites for further reference and study.

Appendices

The appendices contain reference tools and guidelines in learning and practice. These include extended tables for calculating Body Mass Index and a reference list of foods containing oxalates. A table of common conversions between metric and British measurement systems is included for student review. A summary of federal food assistance programs funded and supervised by the U.S. Department of Agriculture and the Administration on Aging, useful for future patient referral, describes the target audience, guidelines for participation, and food resources provided.

Supplementary Materials Available on Evolve

Our Evolve website is designed to provide supplemental online learning opportunities to complement the material in the book. The Evolve website contains sections for both instructor and student resources.

The PowerPoint presentations, Test Bank, and Review Questions were prepared by experienced nutrition writer, editor, and project coordinator, Gill Robertson, MS, RD.

Instructor Resources

- TEACH for Nurses
- Extensive Test Bank of NCLEX-style multiple-choice examination questions
- Image Collection of images from the text
- PowerPoint presentations for each chapter, each created to help guide classroom lecture

Student Resources

- This food database contains over 5000 foods in 18 different categories: Baby Food, Baked Goods, Beverages, Breads/Grains and Pasta, Breakfast Foods/Cereals, Dairy and Eggs, Fats and Oils, Fruits and Vegetables, Meats and Beans, Nuts and Seeds, Frozen Entrees and Packaged Foods, Restaurant Chains–Fast Foods, Restaurant Chains–Other, Seafood and Fish, Snacks and Sweets, Soups, Supplements, and Toppings and Sauces.
- The profile feature allows users to enter and edit the intake and output of an unlimited number of individuals, and the weight management planner helps outline healthy lifestyles tailored to various personal profiles.
- In addition to foods and activities, features include an ideal body weight (IBW) calculator, a basal metabolic rate calculator to estimate total daily energy needs, and sample diets with nutrition recommendations for a variety of conditions.

ACKNOWLEDGMENTS

A textbook of this size is never the work of just authors and contributors. It develops into the planned product through the committed hands and hearts of a number of persons who bring their specialized skills and expertise to its completion. It would be impossible to name all the individuals involved, but several groups deserve special recognition.

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Second, we are indebted to Elsevier and the many persons there who had a part in this extensive project. We especially thank our content strategist, Sandra Clark, whose skills and support have always been invaluable; and our content development specialist, Melissa Rawe, whose creative and energetic talents helped shape the book's pages. We also thank our production project manager, Cindy Thoms, for essential guidance; and our book designer, Brian Salisbury, who helped to bring a new look to this twelfth edition. To our marketing managers and the many fine Elsevier sales representatives throughout the country, we owe great appreciation for their help in ensuring the book's success with users.

Eleanor D. Schlenker
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CONTENTS

APPENDICES

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PART 1

Introduction to Human Nutrition

1

Nutrition and Health

Eleanor D. Schlenker

http://evolve.elsevier.com/Williams/essentials/

*A mother is told that her 11-year-old son, who is **overweight** and sedentary, will likely develop **type 2 diabetes** before he reaches the age of 18. A 23-year-old pregnant woman whose sister delivered a low-birth-weight baby is worried that this may happen to her. A 62-year-old man has been told by his doctor that he has **hypertension** and is at risk of a stroke. A recent edition of the Dietary Guidelines for Americans (DGA) noted that for the first time in our history, the US population could not be described as healthy. Approximately half of all adults have at least one chronic disease, many related to poor eating patterns and low physical activity. Diet-related chronic diseases are affecting our youth, as even adolescents are being diagnosed with elevated blood lipids and high blood pressure. Statisticians predict that today's youth will be the first generation to have a shorter life expectancy than their parents.*

*Nutrition is the cornerstone of a healthy lifestyle. A diet higher in fruits, vegetables, and whole grains and lower in **kilocalories (kcalories or kcal)**, sugar, and fat could help the 11-year-old boy lower his body fat and disease risk. Appropriate food choices support a successful pregnancy. A healthy diet with attention to sodium and potassium can lower the need for medications to control cardiovascular risk. Nutrition is an effective intervention strategy for addressing health problems.*

OUTLINE

In this chapter, we begin our study of nutrition and human health and see how these principles apply to the health problems of the US population. Current knowledge in nutrition reflects our growing understanding of the relationship between food, health, and well-being. Government agencies and institutions charged with reducing chronic disease and containing health care costs are directing attention to what people are eating and what improvements are needed. Access to a safe and wholesome food supply for all must be our goal.

NEW CHALLENGES FOR HEALTH PROFESSIONALS

Our society is constantly changing, and that includes health care and how it is delivered. The rising incidence of chronic disease among all age groups points to the need for lifestyle education and the availability of affordable and healthy food. The Internet and smartphones are adding cost-effective opportunities to deliver information and help consumers distinguish between appropriate and problematic resources. The rise in life expectancy is bringing rapid shifts in population and growing cohorts of older individuals with unique needs. These changes as described later will continue to affect your future practice as a health professional.

Rise in Chronic Disease

In most developed countries, classic nutrient deficiencies have been replaced by diseases of affluence, resulting from a lifestyle favoring an overabundance of food and low physical activity. Nearly half of the US population suffers from at least one chronic condition as described next.[1]

Obesity: Obesity is a major health problem across the globe. Even countries previously facing food shortages and underweight are now experiencing increasing overweight.[2] According to current US statistics, 35% of men and 40% of women are **obese**, and of these nearly 6% of men and 10% of women are classed as severely obese. Over the past decade, obesity rates have stabilized in men but are increasing in women.[3] Twenty-one states have obesity rates of at least 30%, and four states have rates of 35% or higher.[4] Moreover, 39% of men and 26% of women are overweight[5]; less than one-third of US adults are normal weight. Among children and youth ages 2 to 19, 17% are obese.[6]

Diabetes: The rise in obesity has fueled the current diabetes epidemic; 29 million people in the United States have type 2 diabetes and another 86 million are living with prediabetes, putting them at risk of developing diabetes and other chronic conditions.[7] Diabetes and its complications account for 20% of all health care costs. Without intervention, it is estimated that by 2050, one-third of the US population

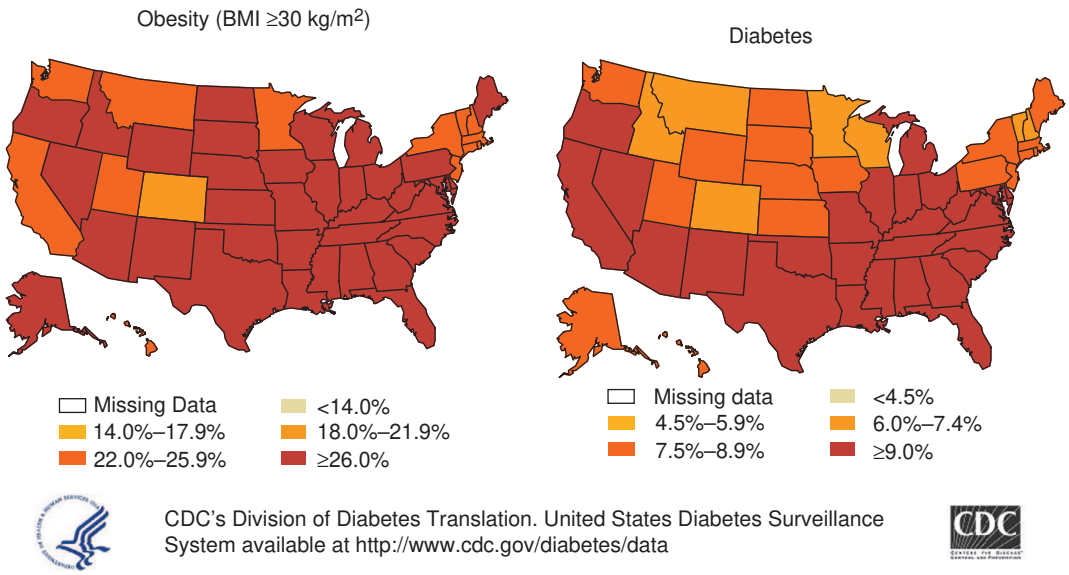

FIG. 1.1 Percentage of US adults who were obese or had diagnosed diabetes in 2015. Notice the relationship between obesity and diabetes; states with a higher prevalence of obesity also had a higher prevalence of diabetes. (Maps from the Behavioral Risk Factor Surveillance System, Centers for Disease Control and Prevention: *PowerPoint Slides on Diabetes,* Maps of Trends in Diabetes and Obesity, Atlanta, GA, US Department of Health and Human Services. https://www.cdc.gov/diabetes/data/center/slides.html.)

will have diabetes. (Note in Fig. 1.1 the pattern of diabetes concentrated in the southern and northeastern regions of the United States.)

Cardiovascular disease (CVD): Heart disease and stroke are among the most widespread and costly health problems and are also among the most preventable. CVD is the cause of one in three deaths, and 20% of these occur in persons under the age of 65. Treatment of CVD accounts for approximately $1 of every $6 spent on health care in the US.[8]

Cancer: Each year more than 1.5 million persons are diagnosed with cancer and more than 500,000 die. In the coming years, cancer is expected to become the leading cause of death as the older population grows in number. On average an individual dying of cancer loses 16.6 years of potential life. More than half of cancer deaths could be prevented through healthy choices, screening, and vaccinations.[9]

Growth of the aging population: Adding to the burden of chronic disease will be the growth of the aging population. Over the past 100 years, life expectancy has risen from approximately 45 years to nearly 80 years, and over the next 50 years the number of persons age 65 and over is expected to double.[10]

Common denominators to the prevention and amelioration of chronic disease, disability, and a deteriorating quality of life is an appropriate diet accompanied by regular physical activity. Recent evaluations of food and nutrient intake and deaths from CVD and diabetes pointed to the protective benefits and detriments to health of particular foods. Fruits, vegetables, legumes, nuts, fish, whole grains, and polyunsaturated fatty acids were protective in preventing these conditions.[11] A greater number of cardiometabolic deaths were associated with higher intakes of sodium, processed meats, and sugar-sweetened beverages and lower use of fruits, vegetables, and fish. Those authors[12] associated dietary intake with 49% of deaths in men and 42% of deaths in women. We will continue to explore the relationships between diet and chronic disease in the following chapters.

Population Diversity and Chronic Disease

As a nation we are becoming increasingly diverse.[13] The numbers of Hispanic Americans, Asian Americans, and Pacific Islander Americans are increasing at rapid rates. Asian Americans are at increased risk of diabetes, likely fostered by a change from a plant-based diet to the typical American diet high in sugar and fat.[14] African Americans develop heart disease, high blood pressure, and diabetes at younger ages than whites and are twice as likely to die of heart disease before the age of 50.[15] Diabetes screening indicates that Hispanic Americans often develop prediabetes before the age of 40.[16] Obesity is a major risk factor for type 2 diabetes in all race and ethnic groups.

Health disparities: Socioeconomic status, race or ethnic group, and availability of health insurance all contribute to disparities in health care across the US population.[17] Approximately one-third of Americans report skipping dental check-ups or using home remedies for existing ailments rather than seeing a doctor. Even those with health insurance report putting off a recommended examination or treatment. Blacks were more likely to avoid getting a prescription filled or to cut pills in half or to skip medicine doses than were whites or Hispanics,[17] likely related to financial limitations. Postponing treatment for a chronic condition such as type 2 diabetes leads to a worsening situation requiring an even greater level of care, and associated disability or premature death. The Centers for Disease Control and Prevention (CDC) has implemented various programs to address health disparities based on (1) language, (2) isolation, and (3) discrimination.[18] Approximately one in five families in the United States speak a language other than English at home; within this group, more than half speak Spanish.[19]

Lifestyle Intervention and Education

Lifestyle education and management is a necessary adjunct to medication in the prevention and control of chronic disease. Our environment, which promotes the consumption of **energy-dense** foods, has contributed to the development of obesity and chronic disease. In contrast to earlier times when humans survived as "hunter-gatherers," we now have a plentiful supply of good-tasting, high-calorie food, with little physical activity required to obtain it. The ever-present vending machine, special offers of two hamburgers for the price of one, and accessible food at all sporting and most social events are factors contributing to excessive food intake (Box 1.1). Portions served at fast food restaurants are at least 2 times larger than those offered 20 years

BOX 1.1 Factors Contributing to Increased Food Intake

- Media advertising of high-sugar and high-calorie foods
- Constant access to vending machines selling high-sugar drinks and high-fat snacks
- More meals eaten away from home
- All-you-can-eat restaurant buffets
- Larger portion sizes both at home and in restaurants
- Continuous snacking
- "Supersizing": a larger portion costing only a fraction more than a smaller portion

ago. Most people increase their energy intake when more food is served, adding to the potential for overeating at "all you can eat" food outlets. We can help prevent overeating by "mindful eating," teaching individuals to be aware of cues that trigger their eating and monitor what foods and how much food they are taking in.

As energy intake has risen, energy expenditure has dropped. For many children, television or video games have replaced active outdoor games, and they ride rather than walk to school. Rural localities and new residential developments lack sidewalks, and many neighborhoods are unsafe for walking. Collaborative efforts among schools, community planners, and health professionals will be required to solve these problems.

The Focus on Culture box, "How Did Our Food Patterns Become So Diverse?" introduces factors influencing the food patterns of populations around the world.

KEY TERMS

Overweight
A body weight greater than the average weight for a person of that gender and body height; this measurement does not distinguish between body fat and body muscle.

Type 2 Diabetes
A form of diabetes mellitus usually occurring in middle or older age in which the body no longer produces or uses insulin effectively; type 2 diabetes is often associated with overweight or obesity and a sedentary lifestyle. (Type 2 diabetes differs from type 1 diabetes in which the body can no longer produce any insulin.)

Hypertension
Medical term to describe high blood pressure; dietary and lifestyle interventions can help lower blood pressure and reduce dependence on antihypertensive medications.

Kilocalorie (kcalorie, kcal)
A calorie is the amount of heat energy required to raise the temperature of 1 g of water from 14° C to 15°C. The kilocalorie equals 1000 small calories and is commonly used to describe the energy content of foods and diets.

Obese
An excessive accumulation of body fat.

Energy-Dense
Term used to describe the relative kcalorie content of a food portion; an energy-dense food may also be nutrient dense if it is a good source of essential nutrients.

FOCUS ON CULTURE

How Did Our Food Patterns Become So Diverse?

Food contains the nutrients that sustain life, but for most of us this is not the reason we eat what we do. Food habits—what we eat and when we eat it—have evolved over thousands of years. In all cultures and societies, various factors have influenced food habits.

Agriculture: Available land for crops or animals led to patterns emphasizing plant or animal foods. Cattle require land for grazing, along with water resources. Parts of Europe were well adapted to raising cattle or pigs, whereas other areas were better suited to goats and sheep for meat and milk. Feta cheese made from sheep or goat's milk is common in Greece and Turkey.

The cereal or grain of a particular region influenced daily meals. Rice, indigenous to Southeast Asia, is served at every meal in traditional Chinese, Japanese, Hmong, and Cambodian households, much the same as bread in the American diet. Because animal foods are limited, the Asian pattern combines a small amount of meat or fish with vegetables and rice for stewlike dishes. Maize or field corn along with rice were the traditional cereals in parts of the United States and Central and South America. Corn bread, corn cake, and popcorn were dietary staples among Native Americans, and corn made into tortillas is the basic grain in Mexican meals.

Climate: When people raised all of their own food, the growing season and amount of rainfall defined what they ate. Root vegetables such as potatoes and cold-hardy cabbage, carrots, and apples were common in northern Europe because they could be stored in a root cellar to sustain families over the winter. In contrast, grains and legumes, along with a bountiful supply of fresh produce, provided the plant base of the healthful Mediterranean diet. Olives, olive oil, and dates remain important foods in Mediterranean cultures. The Caribbean region with its extended growing season is known for its tropical fruits and starchy vegetables.

Proximity to water: Populations living near water included fish or seafood in their daily diet. The typical Japanese meal includes fish or shellfish, along with steamed rice. The French-American (Cajun) foods common to southeast Louisiana have a seafood base and are served over rice.

Religion: Religious beliefs define not only what foods are appropriate but also when they may be eaten. The dietary laws of Judaism are defined in the *Rules of Kashruth,* and foods selected and prepared accordingly are called *kosher,* from the Hebrew word meaning *fit* or *proper.* Jewish law governs how animals are slaughtered with the supervision of a rabbi. Many traditional Jewish foods such as matzo, a type of unleavened bread, relate to significant events in Jewish history.

Muslim dietary laws come from the Quran. As in Judaism, pork is forbidden. Certain foods, including figs, olives, dates, honey, milk, and buttermilk, are believed to have special spiritual and physical value. In the ninth month of the Islamic calendar, Muslims celebrate Ramadan, a 30-day period of daylight fasting during which no food or beverages are eaten from dawn to sunset.

Various foods with particular ethnic and cultural origins have joined the mainstream of American foods. Bagels, a traditional Jewish food, sushi from Japan, and olive oil from the Mediterranean are commonly used by many Americans. A balance between the old and the new preserves one's heritage and health.

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New Directions in Nutrition

New Foods for Health

As nutrition researchers studied the nutrients in food required to prevent deficiency diseases, they also discovered that particular plant foods contain naturally occurring substances in addition to conventional nutrients that positively affect health. These substances, named *phytochemicals* (plant chemicals) and found in fruits, vegetables, and whole grains may play an active role in fighting chronic disease. The foods in which they are found are known as *functional foods*. The finding that certain omega-3 fatty acids found in fish may help prevent CVD has prompted the food industry to develop food sources providing increased amounts of these nutrients. Orange juice has become an alternative source of calcium and vitamin D to prevent bone loss.[20] In contrast, "energy drinks" with added herbs and stimulants and potential deleterious effects on health are being marketed to replace water or other nutritious beverages. Helping consumers make appropriate choices from food in the marketplace is a role for the health professional.

Genes in Nutrition and Health

The Human Genome Project, an international initiative to map the human genetic code, is helping scientists learn how diet interacts with the genetic code and how this affects our nutrient needs and our health. A gene is a DNA sequence that can be translated into a protein, and bioactive components including nutrients, phytochemicals, and functional foods can influence its expression.

Two fields of study have emerged from the Human Genome Project. **Nutrigenomics** is the study of interactions between the components in our diet and our genome, and how this can change the proteins that control our physiology and metabolism. This may explain why individuals respond differently to nutrient supplementation and have greater or lesser nutrient needs.[21] Evaluations of overweight individuals are providing greater insight into how nutrients affect gene expression. When these individuals modify their diet, their energy metabolism is altered, and these findings may enable clinicians to individualize intervention strategies based on a patient's subtype.[22] Alternatively, **nutrigenetics** looks at how individual differences in our genetic code affect our nutrient needs, health status, or risk of particular diseases.[21] Phenylketonuria, the inability of an individual to metabolize the amino acid phenylalanine, results from the lack of the required enzyme and is an example of nutrigenetics. Reviewing family history to determine the risk of chronic disease is another application of nutrigenetics. The presence of certain genes in an individual or family member has been associated with cardiovascular risk, and women with a particular genotype are highly susceptible to breast cancer.[23] Genetic testing carried out by reputable health professionals can provide patients with information that will enable them to implement prevention strategies or follow a more aggressive screening protocol.

In the future, it is likely that health professionals will have the required information to generate personalized dietary advice based on an individual's genetic code; however, we still have much to learn before this becomes a reality. Currently, we can make general recommendations regarding disease prevention for individuals whose family history or medical diagnoses put them at risk, and medical research centers are able to offer genetic counseling in respect to various conditions. However, consumers need to be wary of commercial enterprises offering home DNA kits and mail-order sales of supplements meant to supply the nutrient needs of a particular genotype. Genetic screening and intervention should be obtained through a legitimate health care facility.

Disseminating Nutrition Information

Advances in technology, such as Facebook and smartphones, have revolutionized the way individuals communicate with each other and the outside world. Seventy-seven percent of Americans own smartphones. This includes not only individuals ages 18 to 29 (92% own smartphones) but also 42% of those over age 65.[24] Nearly half of smartphone owners have used this technology to seek health information. Approximately three-fourths of Americans have broadband access at home,[24] and the availability of the Internet at any hour of the day or night has made this a source of ready information. Almost 60% of US adults say they have looked online for health information in the past year; 35% say they have gone online to try to figure out what medical condition they or someone else might have.[25] Caregivers of family members with serious health problems are heavy users of technology on health-related topics. Unfortunately, the accuracy or reliability of the information presented on Internet sites is often suspect. An evaluation of 100 health-related websites conducted by the US Office of Disease Prevention and Health Promotion revealed serious problems in both the credibility of the information presented and the transparency as to who owns the site.[26] Only 30 sites clearly disclosed their identity, and only 15% offered credibility and updating of content. Other shortcomings included failure to disclose authorship of the material presented and clearly differentiating between advertisements and factual content.

Internet sites marketing herbs, drugs, and supplements are not monitored by government regulatory agencies and often contain misleading information. Reputable food companies usually provide helpful facts about the nutrient content of their products, but commercial sites devoted to sales often post misleading claims. Internet sites maintained by government agencies, universities, state extension services, and medical facilities offer evidence-based information and should be the first source for guidance on foods, nutrition, and health. At the close of each chapter in this text is a list of recommended websites for consumers or health professionals seeking additional information.

THE SCIENCE OF NUTRITION

Nutrition builds on two branches of science. The life sciences of biochemistry and physiology tell us how nutrition relates to our physical health and body function. The behavioral sciences help us understand how nutrition is interwoven with our psychosocial needs. Both aspects are at work in our lives.

Human organisms are highly complex groupings of chemical compounds constantly at work in an array of reactions that sustain life. Nutrients participate in and help control these chemical reactions. Various physiologic systems integrate the activities of millions of functioning cells, uniting them into a functioning whole. This highly sensitive internal control is called **homeostasis**.

We also have social and emotional qualities rooted in our earliest awareness. Eating patterns and attitudes toward food develop over a lifetime based on the influences of our primary family and friends, ethnic or cultural group, community, nation, and world. How we perceive food, what we choose to eat, why we eat what we do, and the ways in which we eat are all integral to human nutrition.

Working Definitions

Nutrition means *to nourish* and encompasses the food people eat and how it enriches their lives physically, socially, and personally. From the moment of conception until death, an appropriate supply of food supports optimal growth and maturation and mental and physical well-being. Good nutrition promotes health and reduces the risk of adverse conditions ranging from low birth weight to obesity

to CVD. Food supplies the energy to carry out body functions, such as inhaling and exhaling, maintaining body temperature, and engaging in physical activity. Food also nourishes the human spirit. We all have our particular "soul foods," comfort foods that connect us to our family and provide a sense of psychological and emotional well-being.

To study nutrition, we need to define the terms that describe this body of knowledge and the health professionals who work within it. *Nutrition* refers to the food people eat and how it nourishes their bodies, whereas **nutrition science** defines the nutrient requirements for body maintenance, growth, activity, and reproduction. **Dietetics** is the health profession tasked with the practical application of nutrition science throughout the life cycle in health and disease. The **registered dietitian nutritionist (RDN)** is the nutrition expert on the health care team and, in collaboration with the physician and nurse, carries the major responsibility for a patient's nutritional care. **Public health nutritionists** focus on disease prevention and oversee programs that serve high-risk groups in the community, such as pregnant teens or frail older adults, assessing needs and applying interventions. RDNs cooperate with school nurses to teach weight management classes for children and parents, assist day care providers in planning menus and snacks, or help clients at fitness centers improve their body composition or athletic performance.

Functions of Food and Nutrients

Food serves as the vehicle for bringing **nutrients** into the body; however, the specific chemical compounds and elements in food—the nutrients—are the substances the body needs. No one particular food or food combination is required to ensure health. The human race has survived for centuries on a wide variety of foods, depending on what was available and what the culture designated as appropriate. Approximately 50 nutrients are known to be essential to human life and health, although countless other elements and molecules are being studied and may be found to be essential. The identification of **essential nutrients** (nutrients that the body cannot synthesize) is especially important when developing liquid formulas for feeding critically ill patients.

The **macronutrients** (carbohydrates, fats, and proteins), the **micronutrients** (vitamins and minerals), and water all have important roles in growth and health. The macronutrients supply energy and build tissue, whereas the micronutrients, needed in much smaller amounts, form specialized structures and regulate body processes. Water is the additional and often-forgotten nutrient that sustains all life systems. The sum of all the chemical reactions occurring in the body that use nutrients is referred to as **metabolism**. The first section of this text defines the essential nutrients; later chapters describe how they participate in growth, maturation, aging, and dietary interventions in health and disease.

Nutrients have three general functions, as follows:

1. To provide energy
2. To build and repair body tissues and structures
3. To regulate the metabolic processes that maintain homeostasis.

Energy

All three of the macronutrients—carbohydrate, fat, and protein—can be used for energy, although carbohydrate and fat are the preferred energy sources.

Carbohydrates. Dietary **carbohydrates**—starch and sugars—are the primary sources of fuel for heat and energy. Glucose, the breakdown product of dietary carbohydrate, is the energy currency of the body. *Glycogen* is the storage form of carbohydrate available for quick energy when glucose is needed. Each gram of carbohydrate when metabolized in the body yields 4 kilocalories (kcalories or kcal), known as its **fuel factor**. In a well-balanced diet for a healthy person, 45% to 65% of total kcalories come from carbohydrate.[27]

The majority of these kcalories should be obtained from complex carbohydrates (starch), with a smaller amount from simple carbohydrates (sugars). Another form of complex carbohydrate, known as *fiber,* does not yield energy but has other important body functions. Although the general public uses the word *calorie* to refer to the energy value of food, nutritionists use the technical term *kilocalorie*. As noted later in this chapter, MyPlate (http://www.choosemyplate.gov), the food guidance system developed for the general public,[28] and the DGA[1,29] use the term *calorie* when indicating the energy value of foods or meals.

KEY TERMS

Nutrigenomics
The study of the effects of nutrients and other bioactive substances found in food on genes, body proteins, and metabolites.

Nutrigenetics
The study of the effect of an individual's particular genetic makeup on metabolic and physiologic functions, including nutrient requirements and risk of certain diseases.

Homeostasis
State of dynamic equilibrium within the body's internal environment, a balance achieved through the control of many interrelated physiologic mechanisms.

Nutrition
The sum of the processes involved in taking in food, releasing the nutrients it contains, and assimilating and using these nutrients to provide energy, maintain body tissue, and regulate body metabolism.

Nutrition Science
The body of scientific knowledge developed through controlled research that relates to all aspects of nutrition and its role in the body; areas of study include national, international, community, and clinical nutrition.

Dietetics
The science related to the application of nutrition principles to the selection and preparation of foods and the development of healthy eating patterns for various ages, physiologic situations, health conditions, and diseases.

Registered Dietitian Nutritionist (RDN)
A health professional who has completed an accredited academic program and a minimum of 1200 hours of postbaccalaureate, supervised practice and has passed the National Registration Examination for Dietitians administered by the Commission on Dietetic Registration of the Academy of Nutrition and Dietetics.

Public Health Nutritionist
A health professional who has completed an academic program in nutrition and a graduate degree (MPH or DrPH) in a school of public health accredited by the Council on Education for Public Health, and supervises the nutrition component of public health programs in county, state, national, or international community settings.

Nutrients
Substances in food that are essential for energy, growth, normal body function, and maintenance of life.

KEY TERMS—cont'd

Essential Nutrients
Substances that cannot be made by the body and must be supplied in food. These include essential fatty acids, vitamins, minerals, and essential amino acids for making proteins.

Macronutrients
The three energy-yielding nutrients: carbohydrate, fat, and protein.

Micronutrients
The two classes of non–energy-yielding elements and compounds—minerals and vitamins; these nutrients control and regulate cell metabolism and are components of specialized body structures.

Metabolism
The sum of all the biochemical and physiologic processes by which the body grows and maintains itself (anabolism), breaks down and reshapes tissue (catabolism), and transforms energy to do its work. Products of these reactions are called metabolites.

Carbohydrate
Nutrient class that includes starch, sugar, and fiber; starch should be the major energy source in the diet; sugar and starch have a fuel factor of 4 kcal/g; fiber is an indigestible form of carbohydrate.

Fuel Factors
The number of kcalories that 1 g of a macronutrient yields when completely oxidized; the fuel factor is 4 for carbohydrate and protein, 9 for fat, and 7 for alcohol. Fuel factors are used in computing the energy values of foods and diets (e.g., 10 g of fat yields 90 kcal).

Note: alcohol also adds kcalories to the diet but contains no nutrients. Its fuel factor is 7 kcal/g.

Fat
Nutrient class providing a concentrated form of energy (yields 9 kcal/g); is stored as adipose tissue as an energy reserve; supplies essential fatty acids in the diet.

Protein
Nutrient class that contains nitrogen and essential amino acids; amino acids serve as building blocks for forming body tissues, enzymes, and hormones; fuel factor is 4 kcal/g.

Fats. Dietary **fats** from either animal or plant sources provide an alternate or storage form of energy. Fat is a more concentrated fuel than carbohydrate, with a fuel factor of 9, yielding 9 kcal/g. Nutrition experts recommend that fats supply no more than 20% to 35% of total kcalories.[27] Fats contain the essential fatty acids required for life and health. Saturated fats are a less healthy form of fat; therefore the majority of our dietary fat should be unsaturated.

Proteins. The primary function of **protein** is tissue building, although it can be used for energy if needed. The body draws on dietary or tissue protein for energy when the fuel supply from carbohydrates and fats is not sufficient to meet body needs. Protein yields 4 kcal/g, making its fuel factor 4. Protein can provide 10% to 35% of total kcalories in a well-balanced diet for healthy people.[27]

Tissue Building and Repair

Protein is the primary nutrient for building and maintaining body tissues. Vitamins and minerals are used in smaller amounts in the structure of specialized tissues.

Protein. The basic units of proteins are **amino acids**, the building blocks for body growth and repair. Body tissues are constantly being broken down and rebuilt to ensure growth and maintenance of body structure. Proteins also form vital substances such as enzymes and hormones that regulate body systems.

Minerals. Minerals help build tissues with very specific functions. Two major minerals—calcium and phosphorus—give strength to bones and teeth. The trace element iron is a component of hemoglobin and binds oxygen for transport to cells and carbon dioxide for return to the lungs.

Vitamins. Vitamins are complex molecules needed in very minute amounts but are essential in certain tissues. Vitamin C produces the intercellular ground substance that cements tissues together and prevents tissue bleeding. Vitamin A in the rods and cones of the eye is needed for vision in dim light.

Metabolic Regulation

Specific vitamins and minerals are necessary for enzyme activities responsible for a host of chemical reactions. Water provides the appropriate environment for these reactions to occur.

Minerals. Minerals serve as cofactors in controlling cell metabolism. One example is iron, which controls the enzyme actions in the cell mitochondria that produce and store high-energy compounds.

Vitamins. Many vitamins are components of cell enzyme systems. They govern reactions that produce energy and **synthesize** important molecules. For instance, thiamin controls the release of energy for cell work, and vitamin B_{12} is needed for the synthesis and maturation of red blood cells.

Water. Water forms the blood, lymph, and intercellular fluids that transport nutrients to cells and remove waste. Water also functions as a regulatory agent, providing the fluid environment in which all metabolic reactions take place.

Nutrient Interrelationships

An important principle in nutrition is *nutrient interaction.* It has the following two parts:

1. Individual nutrients participate in many different metabolic functions; for some functions a nutrient has a primary role, and for others it has a supporting role.
2. No nutrient ever works alone.

Intimate and ongoing metabolic relationships exist among all the nutrients and their **metabolites**. Although we look at each nutrient individually to simplify our study, they do not exist that way in the body. Nutrients are always working together within an integrated whole, providing energy, building and rebuilding tissue, and regulating metabolic activities. This synergy and interaction among nutrients is important in carrying out body functions and is sometimes overlooked when we examine the effects of one nutrient at a time.

Nutritional Status

The nutritional health of an individual is known as his or her *nutritional status* and describes how well nutrient needs are being met. Nutritional status is influenced by living situation, social and economic factors, available food, food choices, and state of health. *Nutritional status* differs from *dietary status.* Evaluating nutritional status requires a combination of dietary, biochemical, **anthropometric**, and clinical measurements (Box 1.2), whereas dietary status addresses only what foods are being consumed and their nutrient content. It is important to know not only what an individual is eating, but also whether the body is absorbing and making use of those nutrients. Blood nutrient levels can help identify a

BOX 1.2 Useful Measurements for Evaluating Nutritional Status

Dietary Intake
- What food, where, and when is eaten
- Use of dietary or nutritional supplements
- Money available for food and other food resources
- Therapeutic diet, if any
- Facilities for cooking and storing food

Biochemical Measurements
- Blood protein levels
- Blood lipid levels
- Blood vitamin levels

Anthropometric Measurements (Body Measurements)
- Body weight for height (BMI = kg/m^2)
- Skinfold thicknesses
- Waist circumference

Clinical Evaluation
- Skin
- Hair
- Eyes

nutrient deficiency or a nutrient excess brought about by overuse of highly fortified foods or dietary supplements. Used together, dietary and biochemical measurements can help us distinguish between a *primary nutrient deficiency* and a *secondary nutrient deficiency*. A primary nutrient deficiency is caused by insufficient dietary intake of a particular nutrient or nutrients. A secondary nutrient deficiency is the result of poor absorption or metabolism of a nutrient caused by an interfering substance, a disease or condition, or an elevated requirement. Body weight for height (body mass index [BMI]) and other anthropometric measurements provide estimates of the proportion of body fat versus lean body mass. An evaluation of nutritional status sometimes includes related clinical conditions associated with food and nutrient intake, such as osteoporosis and calcium. Clinical and biochemical parameters included in a nutritional assessment are discussed in detail in Chapter 16; however, when discussing the individual nutrients, we will often refer to the current status of the US population based on the methods listed in Box 1.2.

KEY TERMS

Amino Acid
An acid containing the essential element nitrogen in the chemical group NH2. Amino acids are the structural units of protein and the building blocks of body tissue.

Synthesize
The action of forming new compounds in the body for use in building tissues or carrying out metabolic or physiologic functions.

Metabolites
Any substance produced by metabolism or by a metabolic process.

Anthropometric
Measurement of the human body to determine height, weight, skinfold thickness, or other dimensions that help estimate the relative proportions of body fat and body muscle; these measurements are used to evaluate health status and risk of chronic disease.

Optimal Nutrition

Individuals with optimal nutritional status have neither a deficiency nor an excess of nutrients. Nutrient stores are at the upper end of the normal range. Evidence of optimal nutrition includes appropriate weight for height and good muscle development and tone. Appetite, digestion, and elimination are normal. Well-nourished persons are more likely to be alert, both mentally and physically. They are not only meeting their day-to-day needs but also maintaining appropriate nutrient stores to resist disease and support body function in times of stress.

Undernutrition

Undernutrition takes various forms ranging from marginal nutritional status to the emaciated famine victim. Persons with *marginal nutritional status* are meeting their minimum day-to-day nutritional needs but lack the nutrient stores to cope with any added physiologic or metabolic demand arising from injury or illness, pregnancy, or growth spurt. Marginal nutritional status results from poor choices from the food available, stressful environments, or insufficient resources to obtain appropriate types or amounts of food.

Current US food trends add to the risk of marginal nutritional status and undernutrition among all age groups. Money spent for food away from home has increased and now equals approximately half of total food expenditures.[30] Men between the ages of 20 and 50 consume nearly 40% of their kcalories, fat, saturated fat, and sodium in food away from home but lower proportions of fiber, vitamin A, vitamin D, and calcium.[31] Mixed dishes such as sandwiches, burgers, tacos, pizza, and pasta supply 29% of the total caloric intake of persons age 2 and older; snacks and sweets, including candy, desserts, cake, cookies, and granola bars, make up an additional 16%, and sugar-sweetened soft drinks and fruit drinks add another 12%.[29] Added sugars account for 270 kcal in the average US diet, well above the recommendation that added sugar contribute less than 10% of daily energy intake. Despite an abundance of kcalories, most Americans have less than recommended intakes of fruit, vegetables, whole grains, and dairy items low in fat and added sugar.[29]

Public health nutritionists describe the American diet as energy rich but nutrient poor. Although persons with less-than-optimal intakes of micronutrients may not suffer from overt malnutrition, they are at greater risk of physical illness than those who are well nourished. The body can adapt to marginal nutrient intake but any added physiologic stress that calls on nutrient stores will result in overt malnutrition.

Overt Malnutrition

When nutrient intake is insufficient to meet day-to-day needs and nutrient stores are depleted, signs of malnutrition begin to appear. Limited-resource individuals and families often have diets lacking in food quantity or quality. When asked about their food supply, approximately 12.7% of US households (15.8 million) reported some level of **food insecurity** during the preceding 12 months, meaning they were uncertain of having or being able to acquire a sufficient amount of food for all members of their family.[32] Single-parent families, families with incomes below the poverty line, and minority families are most at risk.

Hunger influences the health of all ages and genders, but the most vulnerable are infants, children, pregnant women, and older adults. Toddlers from families that are food insecure are more likely to have poorer health and experience deficits in cognitive development and academic performance that can extend through adolescence.[33] Children with chronically inadequate diets often develop iron-deficiency **anemia**, with low energy and lessened resistance to infection. Women who are poorly nourished in pregnancy are more likely to give birth to a low-birth-weight infant. Homeless and limited-resource families have low intakes of fruits and vegetables that contain important micronutrients,[34] and these foods are in short supply at many food pantries.[35]

Malnutrition also exists among hospitalized patients and residents of long-term care facilities. Both prescription and over-the-counter medications can diminish appetite or interfere with the absorption of nutrients. Metabolic tests or surgery requiring a prior period of fasting interfere with meals and food intake. Hypermetabolic diseases such as congestive heart failure or cancer increase energy requirements and lead to nutrient depletion and weight loss. Cytokines, secreted by the immune system in response to infection and chronic disease, interfere with the efficient use of nutrients with loss of body protein. In the elderly, even aggressive nutrition intervention cannot always reverse these negative effects.[36]

Overnutrition

Overnutrition takes various forms. Excessive energy intake coupled with low physical activity leads to unwanted weight gain and elevated health risks for chronic conditions such as CVD and diabetes. Overnutrition also occurs with excessive intakes of micronutrients from overuse of dietary supplements. Inappropriate amounts of particular vitamins or minerals damage tissues and interfere with the absorption and metabolism of other essential nutrients. Herbal preparations, growing in popularity, carry the potential for harmful interactions with nutrients or medications.

Nutrient Density

A major factor in nutritional health is the *nutrient density* of the diet. This term refers to the relative nutrient content of a food in relation to its energy content. Nutrition experts[29] define **nutrient-dense** foods as those that provide vitamins, minerals, and other substances that contribute to adequate nutrient intakes or have positive health effects but contain little or no solid fats, added sugars, refined starches, and sodium. A nutrient-dense food contributes vitamins, minerals, essential fatty acids, and/or protein to the diet in addition to kcalories. A food that is not nutrient dense adds kcalories but is lacking in other nutrients. As described in Table 1.1, a hamburger made from lean ground beef, containing only a limited amount of fat, also supplies protein and many vitamins and minerals. Fruits and vegetables high in vitamins and minerals and low in kcalories are nutrient dense. In contrast, a doughnut with high amounts of added sugar and fat and sugar-sweetened soft drinks add only kcalories. These foods we consider to be "**empty calories**" because they contribute no essential nutrients.[37] Americans who consume adequate kcalories may still exhibit undernutrition because the foods they consume are not nutrient dense.

KEY TERMS

Food Insecurity
The limited or uncertain availability of food and the inability or lack of resources to obtain a sufficient supply of nutritionally safe, adequate, and appropriate food through socially acceptable means.

Anemia
A condition characterized by an abnormally low number of red blood cells or cells low in hemoglobin content.

Nutrient Dense
Term used to describe a food that is a good source of at least one essential nutrient in addition to providing kcalories.

Empty Calories
Term used to describe foods high in kcalories and solid fats, added sugar, sodium, or alcohol but containing no or very low amounts of essential nutrients.

NUTRITION POLICY AND NATIONAL HEALTH PROBLEMS

Diet, Health, and Public Policy

Public policy refers to the laws, regulations, and government programs surrounding a certain topic. Nutrition policies are concerned with food guidance for the public, nutrition standards for government food programs, and the health and well-being of the population. Recently, nutrition policy has focused on obesity and related chronic disease. Food safety regulations and nutrition labeling are other examples of public policy.

Prior to 1950, government policies and programs were intended to eradicate hunger and malnutrition. Nutrient deficiency diseases such as rickets and pellagra still existed in various regions of the United States. A law passed in the 1930s mandated the addition of vitamin D to milk as a measure against rickets, and the enrichment of grains with thiamin, riboflavin, niacin, and iron began sometime later to address the problems of pellagra and anemia. The development of the School Nutrition Program with policies for free and reduced-cost lunches was a response to existing hunger among children and adolescents. However, by the 1980s the focus had shifted to overnutrition as new research linked dietary habits to the growing prevalence of CVD.

TABLE 1.1 Nutrient Density of Selected Foods

	Orange Juice (1 cup)	Glazed Doughnut 3-in Diameter (1)	Beef Patty Pan Broiled (3 oz)	Baked Beans Canned, (1 cup)	Sweet Potato, Canned, Mashed (½ cup)	Milk—1% Fat (1 cup)
Kcalories	117	192	197	266	124	118
Fat (g)	—	10	12	1	<1	3
Protein	—	—	◆	◆	—	◆
Fiber	—	—	—	◆	◆	—
Vitamin A	—	—	—	—	◆	◆
Vitamin C	◆	—	—	—	◆	—
Folate	◆	—	—	◆	—	—
Vitamin B_6	◆	—	◆	◆	◆	◆
Calcium	◆ (if fortified)[a]	—	—	◆	—	◆
Iron	—	—	◆	◆	◆	—

[a]Orange juice is not a good source of calcium unless this nutrient has been added.
NOTE: Blue diamonds indicate at least 10% of the Dietary Reference Intakes (DRI); calculations based on DRI values for men ages 19–50. Red diamonds equal 50% or more of the DRI; foods supplying at least 10% of the DRI are considered a good source of that nutrient.
US Department of Agriculture, Agricultural Research Service: *USDA national nutrient database for standard reference*, Release 26, 2013. Nutrient Data Laboratory home page: http://www.ars.usda.gov/nutrientdata.

BOX 1.3 Examples of Nutrition Targets From Healthy People 2020

- Increase the contribution of total vegetables to the diets of individuals aged 2 and older from 0.8 cups equivalent per 1000 calories to 1.2 cups equivalent per 1000 calories.
- Increase the proportion of schools that do not sell or offer calorically sweetened beverages to students from 9% to 21%.
- Increase the proportion of infants who are breast-fed at 6 months from 43.5% to 60.6%.
- Reduce the proportion of US households reporting food insecurity from 14.6% to 6.0%.
- Reduce the proportion of adults aged 18 years and older with hypertension from 29.9% to 26.9% (10% reduction).

Data from US Department of Health and Human Services: *Healthy People 2020: 2020 Topics and Objectives*, Washington, DC, Office of Disease Prevention and Health Promotion, last updated May 2017. https://www.healthypeople.gov/2020/topics-objectives.

Congressional committees and government agencies began to discuss the role of government in setting dietary guidelines to improve health.

The *Surgeon General's Report on Nutrition and Health*[38] released in 1988 established the connection between the typical American diet high in fat and salt and morbidity and early death from CVD. In 1989 the Food and Nutrition Board of the National Academy of Medicine (formerly the Institute of Medicine) issued another extensive report, *Diet and Health: Implications for Reducing Chronic Disease Risk*.[39] Their conclusions agreed with the Surgeon General and people were advised to (1) reduce total fat to 30% or less of total kcalories, (2) reduce saturated fat and cholesterol, (3) increase fiber and complex carbohydrates, (4) avoid excessive sodium and protein, and (5) maintain appropriate levels of calcium.

Healthy People 2020

In 1990 the US Department of Health and Human Services (USDHHS) introduced the public health initiative Healthy People 2000 that established science-based, national objectives for promoting health. These objectives are updated every 10 years and build on the progress made in the decade prior.[40] Healthy People 2020 includes many nutrition-related goals pertaining to dietary intake, maternal and child health, food safety, and management of chronic disease (see examples in Box 1.3). The Healthy People 2020 website presents ideas for related community programs for each objective.

NUTRITION GUIDES FOR FOOD SELECTION

For the past 100 years, government agencies have been issuing food guides to help Americans meet their nutritional needs. The underlying assumptions have been influenced by emerging nutrition science as well as social, political, and economic events, including wars and national emergencies. Their focus also shifted from preventing undernutrition to controlling chronic diseases related to overnutrition. These guides are of three types: (1) nutrition standards, (2) dietary guidelines, and (3) food guides. Each has a different intention and target audience.

Nutrition Standards

Dietary Reference Intakes

Most countries set standards for nutrient intakes of healthy people according to age and sex. Health professionals use these standards in making decisions about the nutritional health of individuals and groups. In the United States these nutrient and energy standards are called the Dietary Reference Intakes (DRIs) and include several categories of recommendations.[27] Each category within the DRIs has a different purpose and use for the health professional. Each category is described next:

- *Dietary Reference Intakes (DRIs):* The framework of nutrient standards that provide reference values for use in planning and evaluating diets for healthy people. The DRIs include the Recommended Dietary Allowance (RDA), the Adequate Intake (AI), the Tolerable Upper Intake Level (UL), and the Estimated Average Requirement (EAR).
- *Recommended Dietary Allowance (RDA):* The daily intake of a nutrient that will meet the requirement of 97% to 98% (or two standard deviations of the mean) of healthy people of a given age and sex. The RDAs were established and are reviewed periodically by an expert panel of nutrition scientists; they are amended as needed based on new research findings. RDAs have been set for carbohydrate, protein, essential fatty acids, and most vitamins and minerals. When planning diets the RDA serves as an intake goal.
- *Adequate Intake (AI):* A suggested daily intake of a nutrient to meet body needs and support health. The AI is used when there is insufficient research available to develop an RDA but the nutrient appears to have a strong health benefit. The AI serves as a guide for intake when planning diets.
- *Tolerable Upper Intake Level (UL):* The highest amount of a nutrient that can be consumed safely with no risk of toxicity or adverse effects. The UL is used to evaluate the nutrient content of dietary supplements or review total nutrient intake from food and supplements. Intakes exceeding the UL usually result from concentrated supplements, not food.
- *Estimated Average Requirement (EAR):* The daily intake of a nutrient that will meet the requirement of 50% of healthy people of a given age and sex. The EAR is used to plan and evaluate the nutrient intakes of groups rather than individuals.
- *Acceptable Macronutrient Distribution Range (AMDR):* The AMDR guides the division of kcalories among carbohydrate, fat, and protein in ranges supportive of health; carbohydrate should provide 45% to 65% of total kcalories, fat should provide 20% to 35% of total kcalories, and protein should provide 10% to 35% of total kcalories.

The DRIs for vitamins and minerals are broken into two age categories for persons over age 50, directing our attention to the changes in nutrient requirements as we age. These two categories are ages 51 to 70 and 71 and older.[27]

The first set of DRIs, replacing earlier RDAs, was released in 1997. They provided new standards for calcium, phosphorus, magnesium, and vitamin D and emphasized their role in bone health. Since then, DRIs have been established for the B-complex vitamins, antioxidant nutrients and carotenoids, vitamins A and K and the trace minerals, energy, the energy-yielding macronutrients and fiber, and electrolytes and water. The DRIs for calcium and vitamin D were revised again in 2010, based on bone health. (These original publications can be found on the website of the National Academy of Medicine (formerly the Institute of Medicine) of the National Academies of Science at https://www.nal.usda.gov/fnic/dietary-reference-intakes.) The Institute of Medicine has recently been renamed the National Academy of Medicine.

The nutrient standards of Canada and Great Britain are similar to those of the United States. Developing countries use standards set by the United Nations Food and Agriculture Organization (FAO).

Dietary Guidelines

Origin of the Dietary Guidelines

Dietary guidelines are the second type of nutrition guide. First published in 1980, the DGA expressed the growing concerns of government agencies about the health of the American people. The *Dietary Guidelines are designed for health professionals who are assisting individuals and managing food and nutrition programs that support a healthy and nutritionally adequate diet. The guidelines (1) give direction to government policies and the development of programs relating to*

nutrition and health, (2) help set standards for food-related programs, such as school meals, and (3) form the basis of nutrition education materials produced and distributed by government agencies.[59]

By law the guidelines are updated every 5 years and represent a cooperative effort between the USDHHS, the federal agency concerned with health, and the US Department of Agriculture (USDA), the federal agency concerned with food. For each update an advisory panel of experts is charged with the responsibility of reviewing the current guidelines, assessing the nutrition and health status of the general population to identify emerging needs and problems, and reviewing new research findings that impact on public health. When complete, the advisory committee's report is submitted for public comment before the specific guidelines are finalized by government experts.[1,29] (See the Evidence-Based Practice box, "How Do I Use It?" to learn more about this method of decision-making.)

Current Dietary Status of the US Population

The current dietary patterns of most Americans include excessive amounts of sodium and added sugar but inadequate amounts of calcium, potassium, vitamin D, and fiber. All age groups, beginning with toddlers ages 1 to 3 years, consume greater than their recommended limits for sodium. Less than one in five Americans meets their recommended servings of vegetables, and barely one in four takes in their recommended servings of fruit. Although most people meet or exceed the number of daily grain servings recommended for their age and kcalories, they are choosing refined grains rather than whole grains. Only approximately 20% of the US population older than age 4 consumes their needed servings of dairy or calcium-fortified foods, putting them at risk of poor bone growth and/or excessive bone loss. Most persons eat more than their recommended amount of protein, with greater amounts from meat, poultry, and eggs and lesser amounts from fish and vegetable sources. Solid fats still exceed oils in the diets of most Americans.[29]

Dietary Guidelines for 2015–2020

The 2015 Dietary Guidelines Advisory Committee took a somewhat different approach than previous committees. Earlier *Dietary Guidelines* emphasized individual dietary components—the food groups and the nutrients. But as noted by the 2015 Advisory Committee,[29] people do not eat nutrients in isolation, but rather as part of an overall eating pattern. It is this eating pattern with its food and nutrition characteristics that over time influences our health and risk of chronic disease. Accordingly, the 2015 guidelines provide three suggested eating patterns to assist individuals in choosing more healthy foods. Each eating pattern is provided at 12 different energy levels, ranging from 1000 to 3200 kcal, and to the extent possible meets the RDA for each nutrient without exceeding kcalorie limits. The three patterns include the following[1,29]:

- *Healthy US-Style Eating Pattern.* This pattern is based on the types and amounts of food that Americans are generally accustomed to eating but suggests nutrient-dense forms and appropriate amounts. It also stays within the recommended limits of overconsumed nutrients such as fat, sodium, and added sugars.
- *Healthy Mediterranean-Style Eating Pattern.* This pattern was adapted from the Healthy US-Style Pattern while adjusting the amounts of certain foods to more closely align with the Mediterranean diet that has been associated with improved health outcomes. This pattern contains more fruits and seafood and less dairy than the Healthy US-Style Pattern.
- *Healthy Vegetarian Eating Pattern.* In this pattern, soy foods such as tofu, legumes, nuts, seeds, and whole grains are increased, and meat, poultry, and seafood are eliminated. Dairy foods and eggs were included as protein sources because recent surveys indicate that a majority of vegetarians use these foods, although the pattern includes suggestions for substitutions if all animal foods are eliminated.[1,29]

These patterns can be viewed in Appendices 3, 4, and 5 of the 2015 DGA, accessible at https://health.gov/dietaryguidelines/2015/guidelines/. To obtain a copy of the 2015 Guidelines publication visit https://health.gov/dietaryguidelines/2015/.

The 2015–2020 Guidelines use five overarching principles to build a framework for healthy eating, yet allow individuals to enjoy foods that meet their personal, cultural, and traditional food patterns (Fig. 1.2).[1] Most people will need to make some changes or *shifts* in

EVIDENCE-BASED PRACTICE

How Do I Use It?

How will you, as a practicing professional, seek out information when developing a nutrition care plan for a patient or client or establishing a nutrition education program? Over time, new evidence becomes available and new interventions are developed. How do you stay up to date on new findings?

The new paradigm in health care is evidence-based practice: using current research and published findings to make appropriate decisions. Successful evidence-based practice requires that you keep current on new standards of practice, carry out planned protocols to evaluate new methods or programs, and share your outcomes with others.

Evidence-based practice is a three-step process, as follows:

- *Identify the problem:* What is the question that you need to answer? Are you developing a new treatment protocol and need some guidance? Do you need some new ideas on how to motivate pregnant teens to consume a healthy diet?
- *Review the evidence:* Search for studies in your professional journals that address this question and critically evaluate what you find. How many patients or clients participated in the evaluation? What was the time period of the study? Were the research participants and circumstances similar to yours? Based on the outcomes of the studies you find, are there some things that you will try to do differently to achieve a better outcome?
- *Implement the findings:* Following your review of the existing information, develop and implement a plan for your patients or group. Be sure to include an evaluation component so you can rate the outcome and success of your plan. When you have compiled your results, share them with other professionals at your facility and at local or state professional meetings.

Nutrition and health experts have developed formal systems for evaluating research evidence. Evidence may be rated as good or strong, fair, limited, or supported only by opinion. These rating scales are used in review articles published in professional journals and on reputable websites maintained by government agencies and professional societies. Make use of these systems in your decision-making process.

Examples of evidence-based approaches to nutrition and health issues follow:

National Institutes of Health, Office of Dietary Supplements: *Herbs at a glance*, November 2016. https://nccih.nih.gov/health/herbsataglance.htm.

US Department of Health and Human Services, US Department of Agriculture: *Scientific report of the 2015 Advisory Committee on the dietary guidelines*, Washington, DC, 2015. https://health.gov/dietaryguidelines/2015-scientific-report/.

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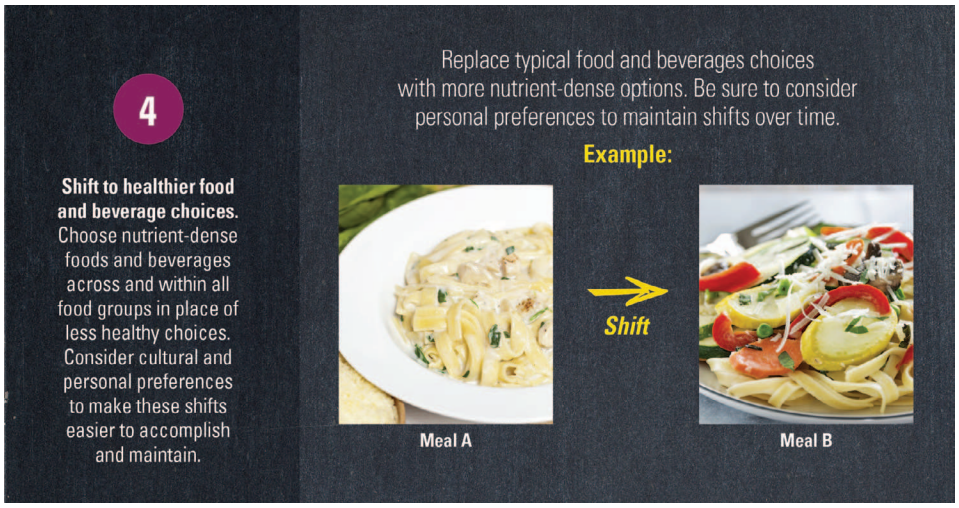
Laramee SH: Evidence-based practice: a core competency for dietetics, *J Am Diet Assoc* 105:333, 2005.

Vaughan LA, Manning CK: Meeting the challenges of dietetic practice with evidence-based decisions, *J Am Diet Assoc* 104:282, 2004.

Zoellner J, Van Horn L, Gleason PM, et al: What is translational research? Concepts and applications in nutrition and dietetics, *J Acad Nutr Diet* 115:1057, 2015.

FIG. 1.2 The 2015–2020 Dietary Guidelines proposes five recommendations for choosing a healthy diet for yourself and others. Make shifts in your eating pattern to accommodate more nutrient-dense foods. Support programs that provide healthy food for all age groups. (US Department of Health and Human Services, US Department of Agriculture: Dietary Guidelines for Americans, 2015–2020, ed 8, 2015.)


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.
Replace typical food and beverages choices with more nutrient-dense options. Be sure to consider personal preferences to maintain shifts over time.
Example:
Shift
Meal A
Meal B

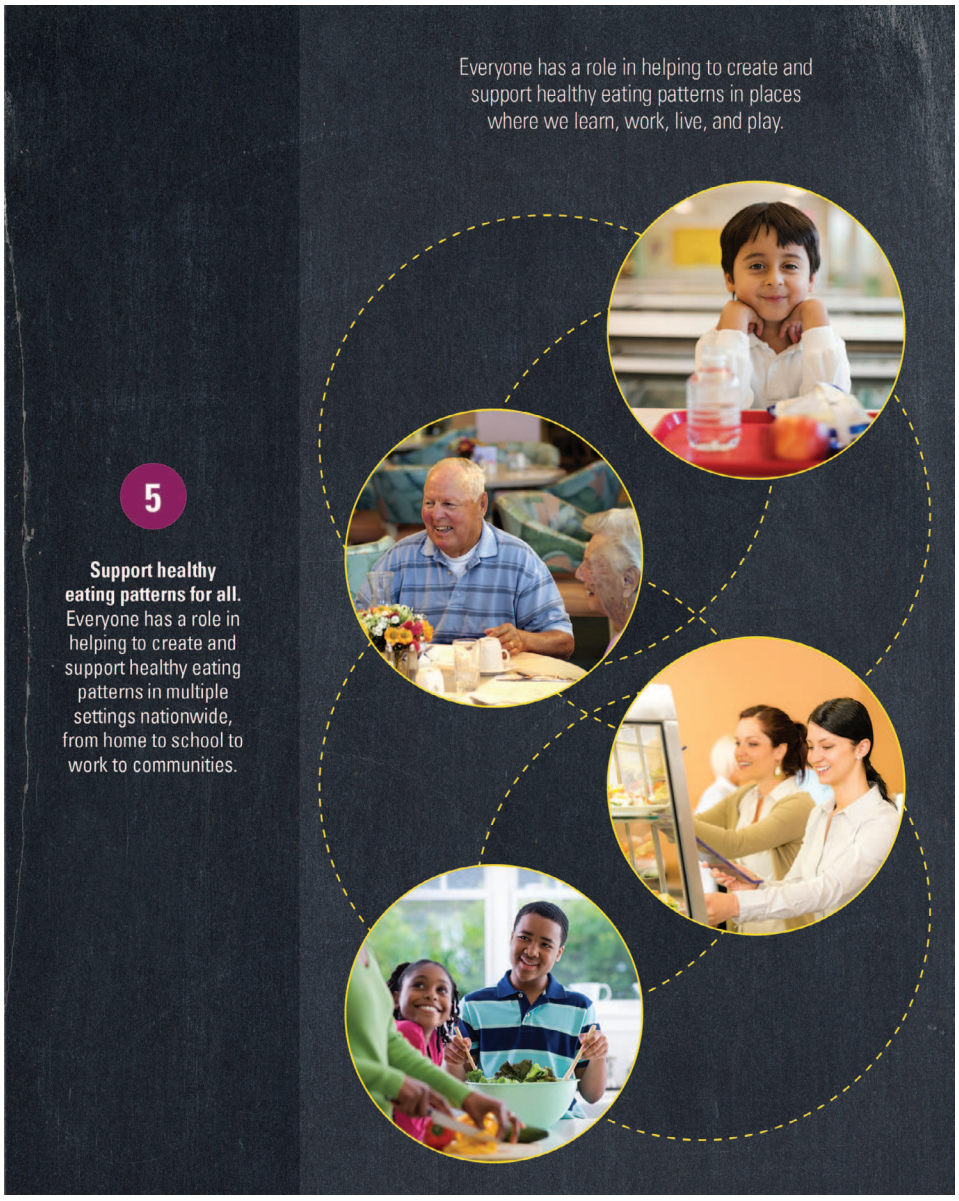

5
Support healthy eating patterns for all. Everyone has a role in helping to create and support healthy eating patterns in multiple settings nationwide, from home to school to work to communities.
Everyone has a role in helping to create and support healthy eating patterns in places where we learn, work, live, and play.

FIG. 1.2, cont'd

their food choices to accommodate the new guidelines, such as choosing foods higher in nutrient density, eating a wider variety of foods, limiting fat, saturated fat, added sugar, and sodium, and shifting to more healthy beverages. The 2015 guidelines, along with the 2008 *Physical Activity Guidelines for Americans*, emphasize daily physical activity in balance with a kcalorie-appropriate diet to maintain a healthy weight.[1] (See Box 1.4 for further details on the 2015 Dietary Guidelines Recommendations.)

Strategies for Implementation

Adoption of healthy shifts in food practices by the American public will require a change in the food environment at home, at school, at the workplace, and in the community. Consumers need access to fresh produce and healthy choices when eating away from home. Food processors must review the kcalorie, sugar, solid fat, and sodium content of their packaged foods. Nutrition programs for children and older adults must incorporate the dietary guidelines in the meals they serve. Snacks offered at community gatherings, sports events, and religious functions must include healthy options. Community leaders must consider the locations of sidewalks, trails, and parks that provide accommodations for walking and other physical activity. All individuals and families must have access to healthy food, regardless of their income. We must develop a plan to enable all Americans to eat well, be physically active, and maintain good health and function.

BOX 1.4 Dietary Guidelines for Americans 2015–2020—Key Recommendations

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

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
- Oils

A healthy eating pattern limits:

- Saturated fats and *trans* fats, added sugars, and sodium

Key recommendations that are quantitative are provided for several components of the diet that should be limited. These components are of special public health concern in the United States, and the specified limits can help individuals achieve healthy eating patterns within calorie limits.

- Consume less than 10% of calories per day from added sugars
- Consume less than 10% of calories per day from saturated fats
- Consume less than 2300 mg per day of sodium
- If alcohol is consumed, it should be consumed in moderation—up to one drink per day for women and up to two drinks per day for men—and only by adults of legal drinking age

In tandem with the previous recommendations, Americans of all ages—children, adolescents, adults, and older adults—should meet the *Physical Activity Guidelines for Americans* to help promote health and reduce the risk of chronic disease. Americans should aim to achieve and maintain a healthy body weight. The relationship between diet and physical activity contributes to calorie balance and managing body weight. People can engage in regular physical activity in a variety of ways throughout the day and by choosing activities they enjoy. (See specific recommendations for various age groups at https://health.gov/dietaryguidelines/2015/guidelines/table-of-contents/).

Taken from US Department of Health and Human Services, US Department of Agriculture: *2015–2020 Dietary Guidelines for Americans*, ed 8, 2015.

Food Guides

Food guides are developed for use by the general public. They are intended to help individuals with day-to-day food selection and meal planning and provide a practical interpretation of nutrition standards and dietary guidelines. Food guides group foods based on their nutrient content and recommend a certain number of servings from each group. Commonly used food guides are the MyPlate[28] developed by USDA which accompanies the DGA, and *Choose Your Foods: Food Lists for Diabetes* from the American Diabetes Association and the Academy of Nutrition and Dietetics.[41] These guides classify foods differently and serve different purposes.

Food Guides

The USDA issued its first food guide in the 1940s, and food guides evolved over time into various formats and shapes. Variations of the Food Guide Pyramid was the graphic used from 1992 through 2009. The need for a new icon that was simple and easy to put into action led to the development of MyPlate, released in 2010.

MyPlate

MyPlate (Fig. 1.3) illustrates the five major food groups using a familiar mealtime visual—a place setting. Food groups join foods with similar nutrient content, and to include more foods similar in nutrients, several food groups were renamed. The traditional meat and beans group was renamed the protein group and the milk group was renamed the dairy group; the fruit, vegetable, and grains groups remained the same. (Table 1.2 describes the nutrients supplied by each food group.)

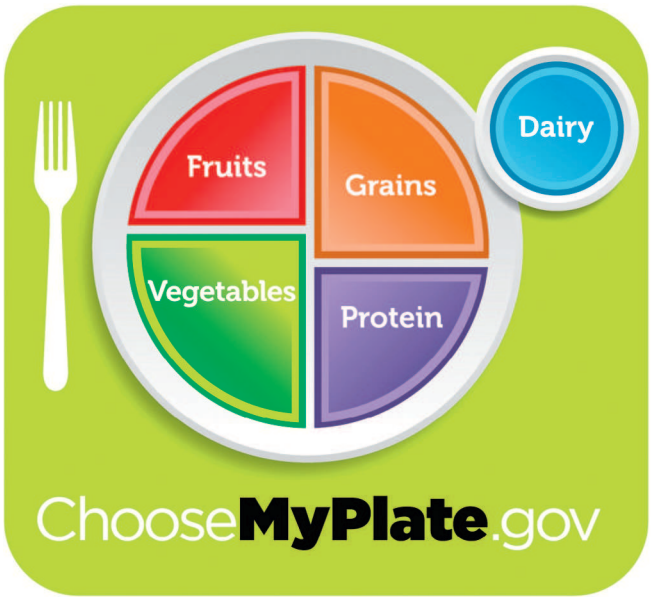


FIG. 1.3 MyPlate: The MyPlate food icon was developed by the United States Department of Agriculture as part of a communication initiative to help consumers make better food choices. MyPlate uses a familiar mealtime setting to remind us to eat healthfully and include appropriate amounts of each of the five food groups. (From US Department of Agriculture, Center for Nutrition Policy and Promotion: *MyPlate [http://www.choosemyplate.gov]*, Washington, DC; last update October 2016.)

TABLE 1.2 Major Nutrients Supplied by Each MyPlate Food Group

Food Group	Major Nutrients[a]	Serving Equivalents
Fruits (color code red)	Vitamin C Folate Potassium Fiber	1 cup raw or cooked fruit or 1 cup 100% fruit juice or ½ cup dried fruit equals 1 cup from the fruit group
Vegetables (color code green)	Vitamin A Vitamin C Vitamin E Vitamin B_6 Folate Potassium Fiber	1 cup raw or cooked vegetables or 1 cup vegetable juice or 2 cups raw leafy greens equal 1 cup from the vegetable group
Grains (color code deep orange) Enriched grains	Thiamin Riboflavin Niacin Folate Iron	1 slice of bread, 1 oz ready-to-eat cereal (approximately 1 cup cereal flakes), ½ cup cooked rice, pasta, or cooked cereal, 1 tortilla (6-inch diameter) or 1 pancake (5-inch diameter) equals 1 oz from the grains group
Whole grains	Zinc, magnesium, and fiber in addition to the nutrients in enriched grains	
Protein foods (color code purple)	Protein Thiamin Riboflavin Niacin Vitamin B_6 Vitamin B_{12}[b] Iron Zinc Vitamin E (nuts)	1 oz lean meat, poultry, or seafood, 1 egg, 1 Tbsp peanut butter, ¼ cup cooked dry beans or peas, or ½ oz nuts or seeds equals 1 oz from the protein foods group
Dairy (color code blue)	Protein Vitamin A Riboflavin Vitamin B_{12} Calcium Phosphorus Magnesium	1 cup milk, 1 cup yogurt, 1 cup fortified soy or rice beverage, 1½ oz natural cheese (e.g., cheddar) or 2 oz processed cheese (e.g., American) equals 1 cup from the dairy group
Other important food components		
Oils (Not a food group but oils supply essential nutrients)	Vitamin E Linoleic acid[c] Alpha-linolenic acid[c]	Includes vegetable, nut, and fish oils and soft vegetable oil table spreads that have no trans fats (Equivalents differ according to source)

[a]Each of the food groups is a major source of the nutrients listed but also adds smaller amounts of other nutrients to the daily diet.
[b]Vitamin B_{12} is found only in animal foods.
[c]Linoleic acid and alpha-linolenic acid are the essential fatty acids.
Data from Dietary Guidelines Advisory Committee, 2005: *Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans 2005,* Beltsville, MD, 2004, US Department of Agriculture, Agricultural Research Service, and US Department of Agriculture and US Department of Health and Human Services: *Dietary Guidelines for Americans, 2010* (Policy Document), ed 7, Washington, DC, 2010, US Government Printing Office.

MyPlate translates the dietary guidelines into action messages for consumers providing menus, recipes, food preparation videos, and best buys at the grocery store that address the barriers to healthy eating—time, money, and cooking skills. Easy-to-read fact sheets supply basic information about foods and their content and ways to reduce your kcalorie intake. The interactive feature, MyPlate Plan, enables consumers to develop individualized daily food plans based on their age, gender, and level of physical activity and generate a daily check list to monitor their personal goals (Fig. 1.4). National surveys indicate that users of the MyPlate website make better food choices than nonusers.[42] Both the dietary guidelines and MyPlate build on current food patterns to encourage Americans to make one small

shift and then another to develop a healthy eating style that they can maintain long term.[43]

Successful implementation of any food plan requires an understanding of serving size and related kcalories, but this concept is poorly understood by the general public. Consumers tend to think of a serving size as what they choose to eat or "what I have on my plate," and this confusion contributes to overeating. The MyPlate Daily Checklist describes serving sizes in household measures (Fig. 1.4), and a helpful illustration of cup and ounce equivalents of various foods can be found in Fig. 1.5. Consumers might be encouraged to measure their food servings for several weeks to establish what standard serving sizes look like. Each food plan developed using the MyPlate Plan feature defines the number of kcalories that can be used for solid fats and added sugars, but note that empty calories are quite limited. The 2000-kcal Daily Check List (see Fig. 1.4) allows only 50 g or 200 kcal of added sugar. MyPlate materials also offer suggestions for measuring your minutes of physical activity.

Food Lists for Meal Planning

Choose Your Food: Food Lists for Diabetes (formerly called the *Exchange Lists*) was introduced in 1950 by the American Diabetes Association and the American Dietetic Association as a meal-planning tool for people with diabetes.[41] The *Food Lists* group foods based on macronutrient content and equivalent energy values, making this tool useful for planning any diet in which control of carbohydrate, fat, protein, and total kcalories is the goal. Because the foods in each list are equal to one another when eaten in the portions indicated, items can be freely interchanged within each list, and food values and kcalories remain constant. The freedom of choice to exchange within groups promotes increased variety and satisfaction with meals and snacks.

USDA United States Department of Agriculture

MyPlate Plan

Find your Healthy Eating Style

Everything you eat and drink matters. Find your healthy eating style that reflects your preferences, culture, traditions, and budget—and maintain it for a lifetime! The right mix can help you be healthier now and into the future. The key is choosing a variety of foods and beverages from each food group—*and making sure that each choice is limited in saturated fat, sodium, and added sugars*. Start with small changes—**"MyWins"**—to make healthier choices you can enjoy.

Food Group Amounts for 2,000 Calories a Day

Fruits	Vegetables	Grains	Protein	Dairy
2 cups	**2 1/2 cups**	**6 ounces**	**5 1/2 ounces**	**3 cups**
Focus on whole fruits Focus on whole fruits that are fresh, frozen, canned, or dried.	Vary your veggies Choose a variety of colorful fresh, frozen, and canned vegetables—make sure to include dark green, red, and orange choices.	Make half your grains whole grains Find whole-grain foods by reading the Nutrition Facts label and ingredients list.	Vary your protein routine Mix up your protein foods to include seafood, beans and peas, unsalted nuts and seeds, soy products, eggs, and lean meats and poultry.	Move to low-fat or fat-free milk or yogurt Choose fat-free milk, yogurt, and soy beverages (soy milk) to cut back on your saturated fat.

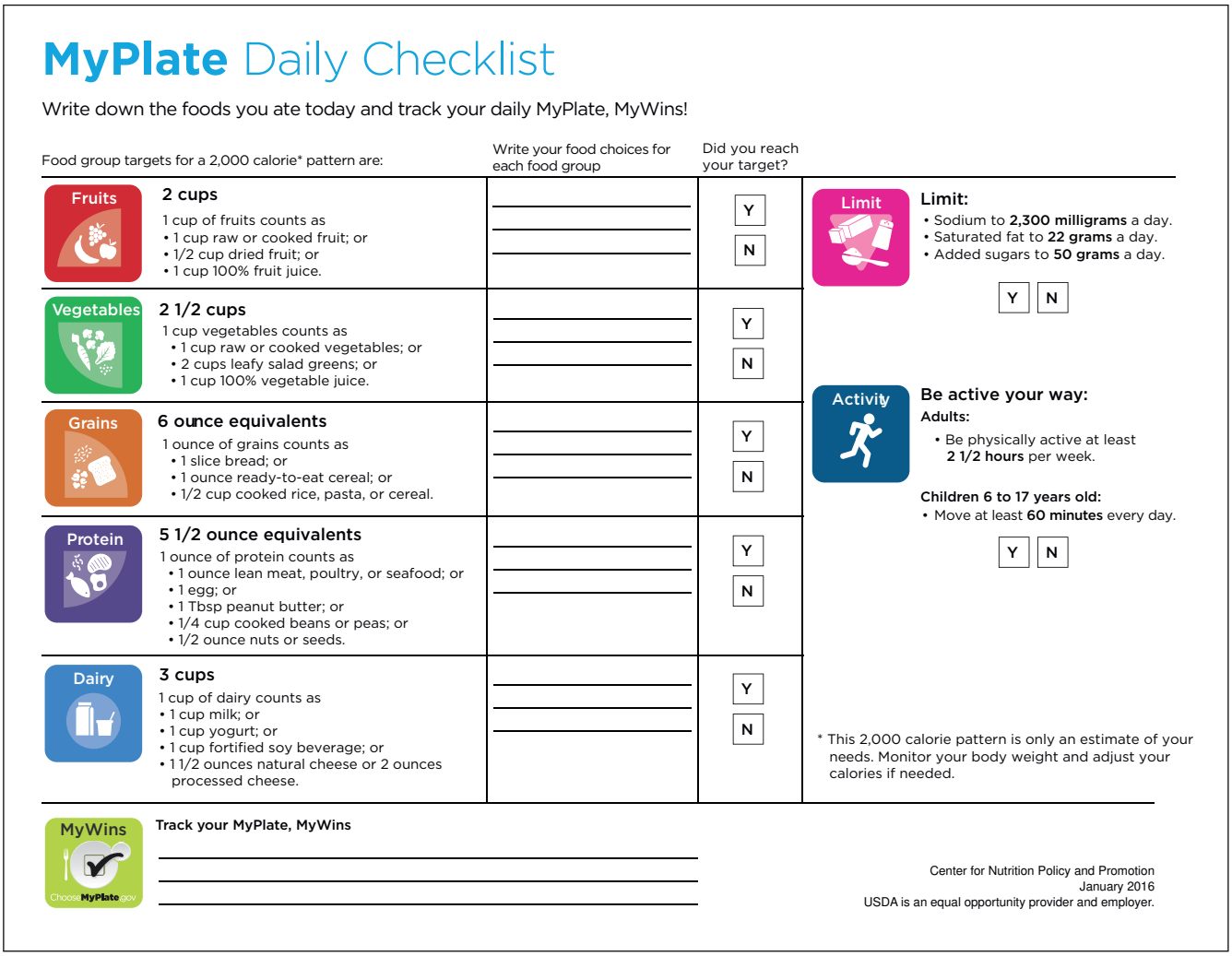
Limit

Drink and eat less sodium, saturated fat, and added sugars. Limit:

- Sodium to **2,300 milligrams** a day.
- Saturated fat to **22 grams** a day.
- Added sugars to **50 grams** a day.

Be active your way: Children 6 to 17 years old should move **60 minutes** every day. Adults should be physically active at least **2 1/2 hours** per week.

FIG. 1.4 The MyPlate Plan is an easy way to track what you had to eat for the day and if you are meeting your goals. The MyPlate Plan indicates the food amounts for a 2000 kcalorie plan. Consumers can access a daily food plan based on their age, gender, body weight, and level of physical activity at https://www.choosemyplate.gov/MyPlatePlan. (From US Department of Agriculture, Center for Nutrition Policy and Promotion: *MyPlate Plan, 2000-calorie daily food plan*, last updated in June 2018; Washington, DC.)



MyPlate Daily Checklist

Write down the foods you ate today and track your daily MyPlate, MyWins!

Food group targets for a 2,000 calorie* pattern are:	Write your food choices for each food group	Did you reach your target?
Fruits — **2 cups** 1 cup of fruits counts as • 1 cup raw or cooked fruit; or • 1/2 cup dried fruit; or • 1 cup 100% fruit juice.		Y N
Vegetables — **2 1/2 cups** 1 cup vegetables counts as • 1 cup raw or cooked vegetables; or • 2 cups leafy salad greens; or • 1 cup 100% vegetable juice.		Y N
Grains — **6 ounce equivalents** 1 ounce of grains counts as • 1 slice bread; or • 1 ounce ready-to-eat cereal; or • 1/2 cup cooked rice, pasta, or cereal.		Y N
Protein — **5 1/2 ounce equivalents** 1 ounce of protein counts as • 1 ounce lean meat, poultry, or seafood; or • 1 egg; or • 1 Tbsp peanut butter; or • 1/4 cup cooked beans or peas; or • 1/2 ounce nuts or seeds.		Y N
Dairy — **3 cups** 1 cup of dairy counts as • 1 cup milk; or • 1 cup yogurt; or • 1 cup fortified soy beverage; or • 1 1/2 ounces natural cheese or 2 ounces processed cheese.		Y N

Limit:
- Sodium to **2,300 milligrams** a day.
- Saturated fat to **22 grams** a day.
- Added sugars to **50 grams** a day.

Y N

Be active your way:

Adults:
- Be physically active at least **2 1/2 hours** per week.

Children 6 to 17 years old:
- Move at least **60 minutes** every day.

Y N

* This 2,000 calorie pattern is only an estimate of your needs. Monitor your body weight and adjust your calories if needed.

MyWins — ChooseMyPlate.gov

Track your MyPlate, MyWins

Center for Nutrition Policy and Promotion
January 2016
USDA is an equal opportunity provider and employer.

FIG. 1.4, cont'd

Choose Your Food: Food Lists for Diabetes[41] arranges foods into the following three groups:

1. *Carbohydrates:* includes starches (grains, starchy vegetables, crackers, snacks, and legumes), fruits, milk, sweets, and nonstarchy vegetables.
2. *Proteins:* includes animal protein foods arranged by fat content (lean, medium fat, and high fat) and plant-based proteins.
3. *Fats:* includes both animal and plant fats arranged by degree of saturation—unsaturated (monounsaturated and polyunsaturated) and saturated.

Serving sizes and macronutrient content for combination foods, fast foods, and free foods are also provided. Use of the *Food Lists* in helping people with diabetes control their carbohydrate intake is discussed in Chapter 22.

A SAFE AND HEALTHY FOOD SUPPLY

Food safety is an important public health priority and included in the Healthy People 2020 initiatives.[40] Foodborne illness arising from microbial contamination, and sometimes incorrectly referred to as "*food poisoning*," is common and costly, yet preventable.[44] The CDC estimates that each year approximately 1 in 6 Americans (48 million people) gets sick; 128,000 are hospitalized; and 3000 die of foodborne illness. The actual number of individuals who get sick from contaminated food is likely higher because many cases go unreported when people attribute their symptoms to a "stomach virus" or the flu and do not seek medical care. Symptoms of foodborne illness include diarrhea, nausea, and stomach upset and cramping. In most cases, victims feel better in 1 or 2 days; however, in young children, older adults, and patients with compromised immune systems, foodborne pathogens result in severe dehydration, fever, hospitalization, and even death. Careful washing of fresh produce, especially leafy vegetables; thorough cooking of poultry and raw meat; avoiding raw eggs (including not tasting batters containing raw eggs); and always washing your hands before eating and cooking help prevent foodborne illness. Proper food handling should be included in any comprehensive nutrition education program. In Chapter 9 we explore these topics in greater depth.

PERSONAL PERCEPTIONS OF FOOD

What Do I Usually Eat

Each of us develops ways of eating based on our ethnic or cultural background, religious beliefs, family habits, socioeconomic status,

FIG. 1.5 Serving sizes for various foods. Increasing portion sizes have helped to fuel the growth in overweight and obesity. The 2015–2020 Dietary Guidelines for Americans has provided illustrations of cup and ounce equivalents that can help control your kcalorie intake. (From US Department of Healthand Human Services, US Department of Agriculture: Dietary Guidelines for Americans, 2015–2020, ed 8, 2015.)

health status, geographic location, and personal likes and dislikes. However, the growing ethnic and cultural diversity in our society has brought about a greater intermingling of foods and ideas about food. How people perceive themselves in relation to food and food patterns plays a role in their attitudes toward food and personal eating behavior.

A simple way to get an idea of your own food pattern and beliefs is to look at what you actually eat. See the Perspectives in Practice box, "My Personal Food Patterns: Do They Need Improvement?" for directions on keeping a food diary. Keeping a record of everything you eat and drink for a day, noting the time, place, any related activity, and people with you provides insight to your true relationship with food. Most of us eat by habit, according to where we are and what is available, rather than by serious thought or plan. Using MyPlate to approximate kcalorie needs and required food servings is a means of rapid dietary assessment.

PERSPECTIVES IN PRACTICE

My Personal Food Patterns: Do They Need Improvement?

Before we can help others make healthy food choices, we need to help ourselves. What do you usually eat? Do you eat regular meals or snack most of the time? Do you make an effort to choose nutritious foods or eat whatever is around? This activity provides an opportunity to evaluate your personal food and nutrient intake.

- To get started, keep a detailed record of everything you eat and drink for 3 days: 2 weekdays and 1 weekend day. List the type and amount of food in household measures (e.g., cups, tablespoons, or dimensions), how it was prepared, and brand name, if applicable. Be specific: was your milk nonfat, 1% fat, 2% fat, or whole? Include butter, margarine, salad dressings, condiments, and additions to coffee or tea. When you have completed your record, consider the following:
- What social or emotional factors influenced your food choices? Where and when did you eat? Were you alone or with someone? How did you feel at the time?
- Using MyPlate, compare your intake with the number of servings and serving sizes recommended for your age, gender, and level of physical activity. Did you have too many or too few servings from any of the food groups?
- Using the Nutritrac software available on the Evolve website, evaluate your intakes of macronutrients and micronutrients. Are your kcalories partitioned appropriately? How do your intakes compare with the DRIs for your age and gender?
- Now that you have thought about it, how do you view your diet? Do you have food behaviors that you should modify to promote good health? Do you feel good about certain nutrient categories for which you are meeting current recommendations? If improvements are needed, develop a plan for making changes over time that are consistent with your lifestyle and resources and can be sustained.

Nutritional Analysis by Nutrients and Energy Values

A comprehensive nutritional analysis of food intake is accomplished using a computer-assisted nutrient analysis program, as found on the Evolve website that accompanies your text. A computer-assisted program enables you to evaluate individual intakes of vitamins and minerals, protein, specific fats, fiber, and energy as compared with the DRIs. Government agencies use such analyses to evaluate dietary information obtained in national surveys and to identify nutrition problems among various age, gender, or ethnic groups.

HEALTH PROMOTION

Healthy People 2020,[40] the National Institutes of Health,[45] and nonprofit health groups such as the American Heart Association[46] are encouraging population approaches to health promotion to reach more people with important health messages. Such approaches include the use of media including public service announcements and newspapers, package labeling, school programs, worksite programs, and community programs sponsored by local coalitions, health facilities, and other health organizations. The most effective community programs involve several activities that reach a broad base of consumers and reinforce the messages in various ways. Several of the Healthy People 2020 objectives pertain to childhood obesity, and schools are well positioned to reach children and families with in-school and after-school activities.

A comprehensive school program could include the school nutrition program, school nurse, teachers, parents, parent-teacher association, and local health care professionals as follows:

- *School food service:* Review menus to conform to current guidelines limiting fat, sodium, and sugar and emphasizing fruits, vegetables, and whole grains; offer fruit or cereal-based treats for dessert; provide fresh fruit as a snack.
- *School art department:* Sponsor a student contest for posters or displays that "advertise" healthy cafeteria options or encourage students to drink water rather than sugar-sweetened beverages.
- *School health/physical education curriculum:* Discuss healthy eating and ways to limit kcalorie intake if you are gaining unwanted weight; support physical activities that are feasible for students of all body weights; set up an after-school walking club.
- *Parent/teacher organization:* Have a local health professional speak about childhood overweight and intervention strategies; review fundraising policies and determine whether sale items or vending machine contents are in balance with child obesity prevention.
- Engage the local hospital or a health group in sponsoring a walking event for the community at large with emphasis on "getting in the game" rather than how far or how fast a participant can walk. Make step counters available to encourage continued walking.

Health promotion must be ongoing and advance a consistent message across the community. Programs are most successful if they stress specific goals relating to food or activity rather than overall healthy living.[46] Just as poor eating and activity patterns develop over time, so must intervention be a continuing process. As a health professional, look for other programs and individuals with similar goals with whom you can partner to maximize your impact on community health.[47] (We will learn more about organizing community interventions in Chapter 10.)

TO SUM UP

The role of nutrition in human health continues to evolve in response to our changing society and food supply. As available food increased and the physical activity required to obtain it decreased, inappropriate weight gain, diabetes, and CVD have emerged as major health problems worldwide. Discovery of new substances in plant foods that are beneficial to health led to the definition of functional foods and recommendations for their use. Despite the accessibility of nutrient-dense foods, many American diets are high in sugar, fat, and sodium, compromising nutritional status. Children and adults who are chronically undernourished as a result of illness, disease, or inadequate food resources are more vulnerable to poor growth, infection, and nutrition-related diseases. Resources developed by government agencies are helpful in planning and evaluating the nutrient intakes of all population groups. The DRIs and the DGA, intended for use by health professionals, provide the foundation for MyPlate, which offers practical guidance for family meal planning. Together, these materials build a framework for public policy that directs state and federal nutrition programs and develops health messages reaching people of all ages.

QUESTIONS FOR REVIEW

1. Visit the Maps of Trends in Diagnosed Diabetes and Obesity, produced by the Centers for Disease Control and Prevention at https://www.cdc.gov/diabetes/statistics/slides/maps_diabetesobesity_trends.pdf and scroll down to the state maps and diabetes and obesity statistics. What is the prevalence of obesity and diabetes in your state as compared with national trends? How have they changed over the past 20 years? Note how the growth in diabetes prevalence has paralleled the rise in obesity prevalence.
2. What are the two major fields of science that provide the foundation for the study of nutrition? What does each contribute to our understanding of human nutrition needs?
3. Compare the four levels of nutritional status: optimal nutrition, marginal nutrition, undernutrition, and overnutrition. In what community or clinical situations might you expect to find individuals representing each of these conditions and what physical or clinical signs would you use to identify them?
4. What are the six major nutrient groups? What is the primary function of each?
5. What are the various categories within the DRIs? What is the purpose of each?
6. Compare nutrient standards, dietary guidelines, and food guides: (a) list an example of each, (b) the intended audience (professional or consumer), (c) the type of information included, and (d) a professional situation in which you would use it.
7. Visit the Healthy People 2020 website at https://www.healthypeople.gov and look for a nutrition or health objective of interest. Review the target goals and suggested community-based interventions for that objective. Choose a target audience in your community and develop an intervention that would address this health issue.
8. Research the food patterns of a cultural or ethnic group different from your own. Using MyPlate, develop a 1-day menu for a child or adult in that group using foods common to their daily pattern.

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2

Digestion, Absorption, and Metabolism

Eleanor D. Schlenker

http://evolve.elsevier.com/Williams/essentials/

We continue our study of nutrition by looking at what happens to food as it follows its path through the digestive system to be broken down into forms the body can use. We see how the tuna sandwich we had for lunch is transformed into the energy-yielding and tissue-building nutrients—glucose, amino acids, and fatty acids. These physiologic and biochemical actions include three parts: digestion, absorption, and metabolism. Although we give little thought to these activities when all are working well, functional changes in the gastrointestinal tract can lead to nutrient deficiency and deteriorating health, loss of pleasure in eating, and poor quality of life. Through the actions of its abundant species of bacteria, the intestine may also help regulate immune function, inflammation, and obesity.

OUTLINE

HUMAN BODY: THE ROLE OF NUTRITION

FOOD: CHANGE AND TRANSFORMATION

The food we eat contains the nutrients necessary for our survival, but these nutrients must first be released from other food components and transformed into units the body can use. Through a sequential and interrelated system, foods are broken down into increasingly simple substances that can enter the metabolic pathways in cells. Each section of the gastrointestinal tract has a unique function, but together they form a continuous *whole.* A problem in one segment has clinical consequences for the entire system.

IMPORTANCE FOR HEALTH AND NUTRITION

Gastrointestinal function impacts nutritional well-being. Food, as it occurs in nature and as we eat it, is not a single substance, but a mixture of nutrients and other chemical matter. These substances must be separated so the body can handle each one as an individual unit. Nutrients released from food remain unavailable to the body until they cross the intestinal wall and enter the circulatory system for transport to tissues. Diseases affecting the organs of the gastrointestinal tract or the absorbing surface of the intestinal wall have adverse effects on nutritional status because nutrients are not taken into the body in the amounts needed. At the same time, moderate to severe malnutrition lowers secretion of digestive enzymes and blunts the absorbing structures, further limiting digestion and nutrient passage. This vicious cycle results in rapid and progressive deterioration in nutritional health.

The output of the gastrointestinal tract is also essential for the chemical work that occurs in tissues and cells. This integrated physiochemical system is fundamental to human nutrition in both health and disease. The internal control responsible for maintaining a constant chemical environment and coordinating the activities of the body's many functional systems is called **homeostasis**.

KEY TERM

Homeostasis
State of dynamic equilibrium within the body's internal environment; this balance is achieved through the operation of many interrelated physiologic mechanisms.

GASTROINTESTINAL TRACT

Component Parts

The gastrointestinal tract, also called the *alimentary canal,* is a long hollow tube that begins at the mouth and ends at the anus. The specific parts that make up the tract are the mouth, esophagus, stomach, small intestine, large intestine or colon, and rectum. Other organs that lie outside the tract but support its work by secretion of important

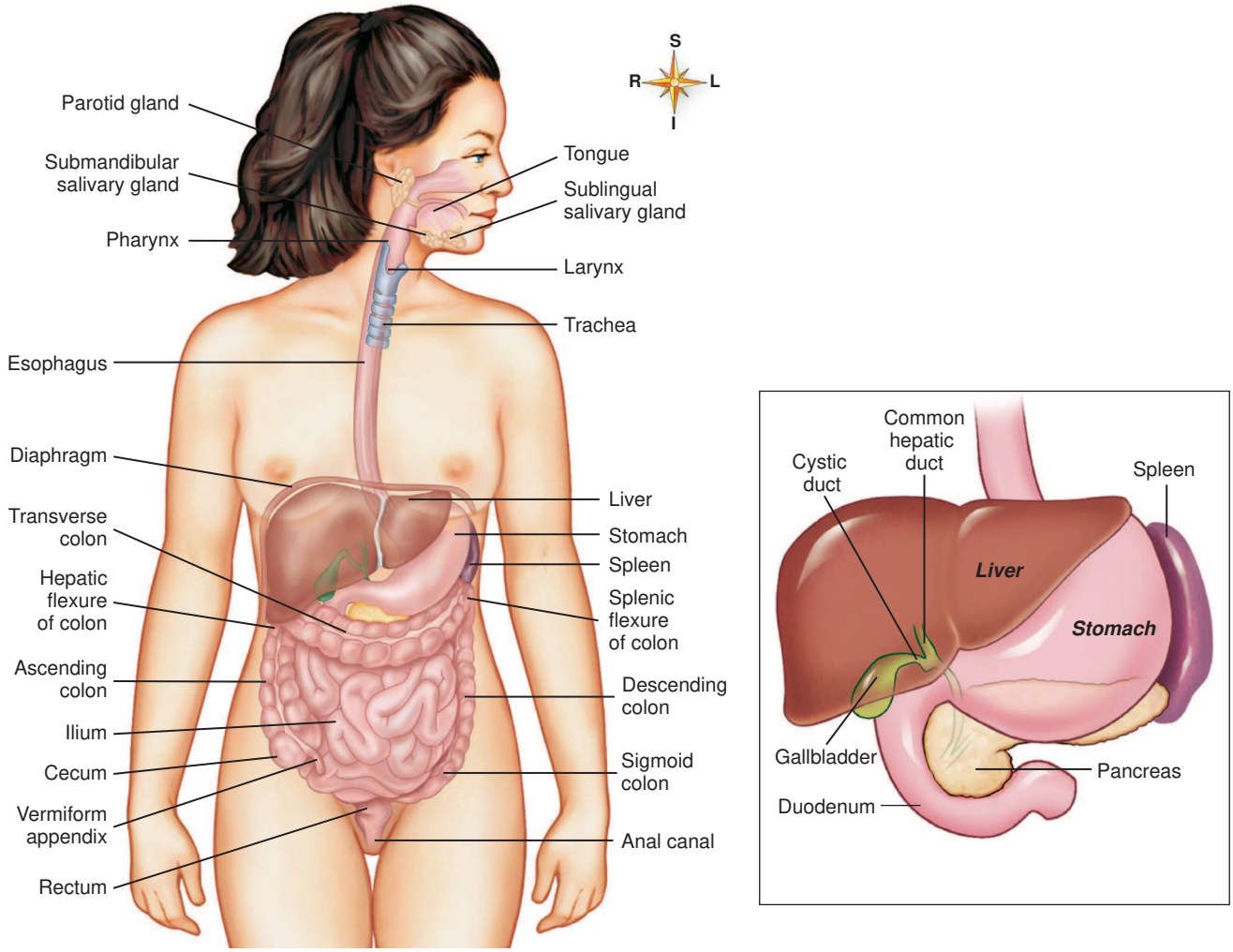

FIG. 2.1 The gastrointestinal system. The successive parts of the gastrointestinal system carry out multiple activities of digestion that liberate and reform food nutrients for our use. (From Thibodeau GA, Patton KT: *Anatomy and physiology,* ed 7, St. Louis, 2010, Mosby.)

enzymes and digestive fluids are the pancreas, gallbladder, and liver. Fig. 2.1 presents the respective components of the gastrointestinal tract and their relative position to one another. These organs, working as a team, can break down and/or absorb several kilograms of carbohydrate, one-half kilogram of fat, one-half kilogram of protein, and 20 or more liters of water daily.[1] We will follow these food components as they travel together through the successive parts of the tract.

General Functions

The gastrointestinal tract has the following four major functions:

1. *Receives food:* The mouth is the entrance to the gastrointestinal tract. From here the food moves to the stomach and other organs for digestion and absorption.
2. *Releases nutrients from food:* Digestion and the separation of nutrients from other food components take place in the stomach and small intestine.
3. *Delivers nutrients into the blood:* Absorbing structures called *microvilli* located in the small intestine transfer the nutrients into the portal blood (glucose and amino acids) or lymph (fatty acids). Water is absorbed later in the colon.
4. *Excretes nondigestible waste:* The fecal mass moves from the colon into the rectum, where it is stored until excreted.

Physical and chemical actions accomplish these tasks.

Sensory Stimulation and Gastrointestinal Function

Both physiologic and psychological stimuli influence the gastrointestinal tract. The physical presence of food in the mouth, stomach, or small intestine initiates a variety of responses that coordinate the muscular movements and chemical secretions necessary for digestion and absorption. Sensory stimuli, such as seeing, smelling, or being close to food, prompt the secretion of digestive juices and muscle motility. Smelling cookies baking, hearing foods sizzle on an outdoor grill, or picking a fresh berry can evoke the physiologic process of digestion. Seeing a sign that advertises your favorite food (or even thinking about food) stimulates the gastrointestinal tract. At the other extreme, dreading an unpleasant-tasting medication or recalling the nausea brought on by chemotherapy can repress the desire for food.

The neural responses resulting from the presence or thoughts of food have an important role in food intake and the digestive process. Neural responses prepare the gastrointestinal tract to receive food by initiating the secretion of enzymes and digestive fluids and promoting gastrointestinal motility. They also control the secretion of hormones that influence appetite, food intake, and satiety.[2] Inappropriate changes in neural regulation that result in feelings of satiety early in the meal limit food intake in some older adults, leading to unwanted weight loss. Maintaining positive associations with food and mealtime supports efficient digestion and absorption of nutrients.

PRINCIPLES OF DIGESTION

Digestion, the complicated process by which food is broken down and nutrients released, converts food for body use. Digestion involves two types of actions:

- Chemical breakdown of food into its constituent parts through the action of enzymes and other specialized fluids. Each chemical agent acts on a particular macronutrient in a specific region of the gastrointestinal tract.
- Muscular action including mechanical mixing and propulsive movements controlled by neuromuscular, self-regulating systems. These motions work together to move the food mass along the alimentary canal at the best rate for digestion and absorption.

Gastrointestinal Secretions

Food is digested chemically through the combined action of various secretions of the following four types.

1. *Enzymes:* Certain enzymes attack designated chemical bonds within the structure of nutrient compounds, freeing their component parts.
2. *Hydrochloric acid and buffer ions:* These secretions produce the pH necessary for the activity of certain enzymes.
3. *Mucus:* This sticky, slippery fluid lubricates and protects the inner lining of the gastrointestinal tract and eases the passage of the food mass.
4. *Water and electrolytes:* These agents provide appropriate solutions in the amounts needed to circulate the substances released in digestion.

Special cells in the mucosal lining of the gastrointestinal tract and in adjacent accessory organs, especially the pancreas, produce these secretions. Their release is stimulated by (1) the presence of food in the tract; (2) the sensory nerve network activated by the sight, taste, or smell of food; and (3) hormones specific to certain nutrients.

Gastrointestinal Motility: Muscles and Movement

Types of Muscles

Organized muscle layers in the gastrointestinal wall provide the motility needed for digestion (Fig. 2.2). From the outer surface inward, the layers are (1) the **serosa**, (2) a longitudinal muscle layer, (3) a circular muscle layer, (4) the submucosa, and (5) the **mucosa**. The coordinated interaction of four smooth muscle layers makes possible four different types of movement (Fig. 2.3), as follows:

1. *Longitudinal muscles:* These long, smooth muscles arranged in fiber bundles extend lengthwise along the gastrointestinal tract and help propel the food mass forward.
2. *Circular contractile muscles:* The circular smooth muscle fibers extend around the hollow tube forming the alimentary canal. These contractile rings initiate rhythmic sweeping waves along the tract, pushing the food mass forward. These regularly occurring propulsive movements are called **peristalsis**.
3. *Sphincter muscles:* At strategic points, muscle sphincters act as valves—pyloric, ileocecal, and anal—to prevent reflux or backflow and keep the food mass moving in a forward direction.
4. *Mucosal muscles:* This thin embedded layer of smooth muscle produces local constrictive contractions every few centimeters. These contractions mix and chop the food mass, effectively churning and mixing it with secretions to form a semiliquid called **chyme** that is ready for absorption. In summary, the muscles lining the gastrointestinal tract produce the following two types of action:
   - **Tonic** contractions that ensure continuous passage of the food mass and valve control
   - Periodic rhythmic contractions that mix and propel the food mass forward

The alternating contraction and relaxation of these muscles along the tract facilitate digestion and absorption.

Nervous System Control

Throughout the gastrointestinal tract, specific nerves regulate muscle action. An interrelated network of nerves within the gastrointestinal wall called the **intramural nerve plexus** (Fig. 2.4) extends from the esophagus to the anus. This network of approximately 100-million nerve fibers regulates the rate and intensity of muscle contractions, controls the speed at which the food mass moves along the tract, and coordinates the digestive process, including the secretion of enzymes and digestive juices.[3]

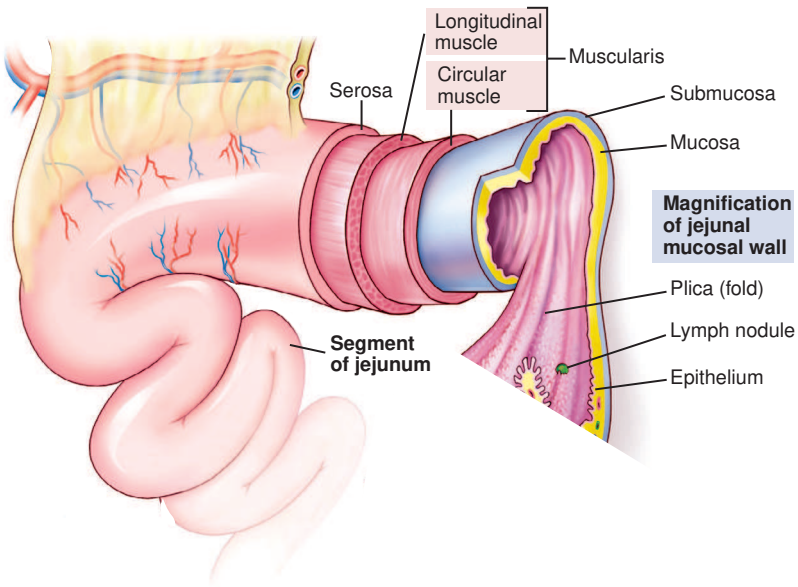

FIG. 2.2 Muscle layers of the intestinal wall. Notice the five layers of muscle that produce the movements necessary for digestion and moving the food mass forward. (Modified from Thibodeau GA, Patton KT: *Anatomy and physiology,* ed 7, St. Louis, 2010, Mosby.)

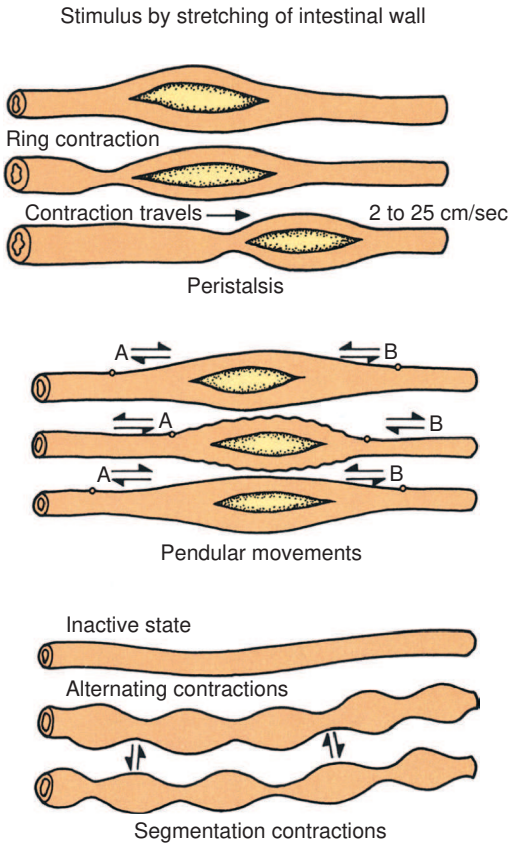

FIG. 2.3 Types of movement produced by muscles of the intestine: peristaltic waves from contraction of deep circular muscle, pendular movements from small local muscles, and segmentation rings formed by alternate contraction and relaxation of circular muscle.

KEY TERMS

Digestion
The process of breaking down food to release its nutrients for absorption and transport to the cells; both the chemical action of numerous enzymes and fluids and the mixing and churning action of the embedded musculature accomplish this task.

Serosa
Outer surface layer of the intestines interfacing with the blood vessels of the portal system that go to the liver.

Mucosa
The mucous membrane forming the inner surface of the gastrointestinal tract that has extensive nutrient absorption and transport functions.

Peristalsis
A wavelike progression of alternating contraction and relaxation of the muscle fibers of the gastrointestinal tract that keeps the food mass moving forward.

Chyme
Semifluid food mass resulting from gastric digestion.

Tonic
Ongoing low-level muscle contraction and relaxation

Intramural Nerve Plexus
Network of nerves in the walls of the intestine that control muscle action and secretions for digestion and absorption.

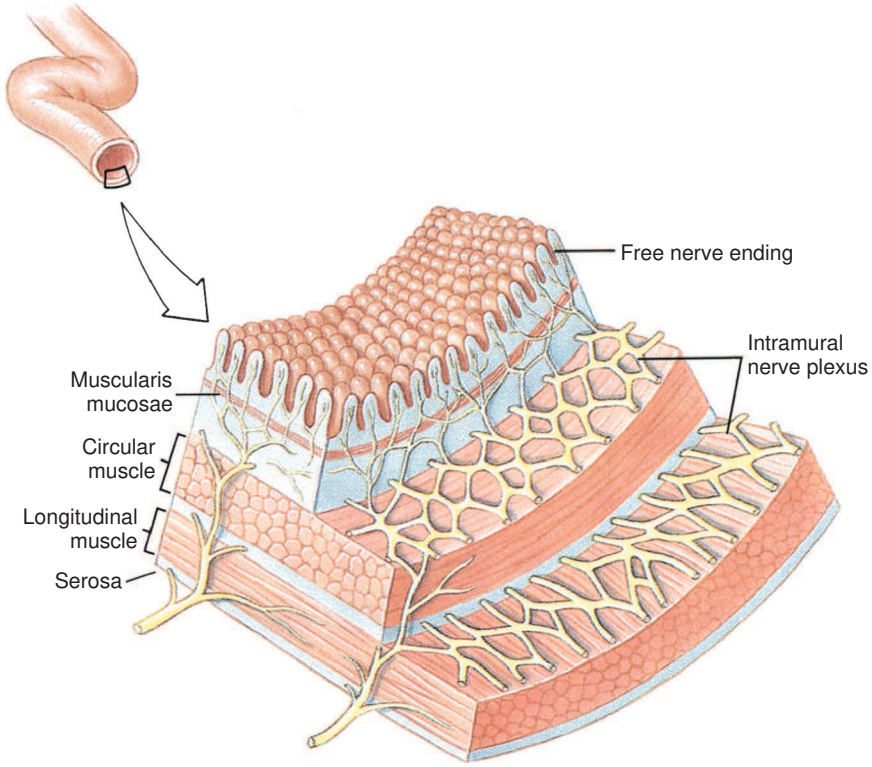

FIG. 2.4 Innervation of the intestine by the intramural nerve plexus. A network of nerves controls and coordinates the movements of the intestinal muscles. (Courtesy Medical and Scientific Illustration.)

MOVEMENT OF FOOD THROUGH THE DIGESTIVE TRACT

We have reviewed the integrated muscular and secretory functions that govern the overall operation of the gastrointestinal tract; now we will follow this process through its successive stages to see what happens to the food we eat.

MOUTH AND ESOPHAGUS: PREPARATION AND DELIVERY

Eating begins the process by which food is broken down into individual nutrients. The first steps in digestion occur in the mouth, where salivary enzymes act on carbohydrate and all foods are broken down into smaller particles to facilitate the later action of digestive juices. The esophagus delivers the food mass to the stomach.

Taste and Smell

Much of our enjoyment of food comes from its unique flavors and aromas. Taste buds located on the tongue, roof of the mouth, and throat contain chemical receptors that produce the four sensations of taste: salty, sweet, sour, and bitter. Recently, a fifth taste has been identified, called *umami,* the taste of amino acids and proteins. Some individuals have a stronger perception of one taste over another, and certain medications produce a bitter taste or loss of taste. Genetically related differences in taste affect our preferences for certain foods.[4] Individuals with enhanced sensitivity to bitter taste might avoid certain fruits and vegetables or prefer sweet or high-fat foods. Such taste preferences that influence what we eat also affect our risk for obesity or particular chronic diseases or conditions.[5] Patients on chemotherapy often have distorted taste (dysgeusia). Smoking also results in changes in taste. Zinc deficiency causes a loss of taste (hypogeusia).

Foods contain volatile components that move from the back of the mouth up into the nasal cavity, where they act on olfactory receptors to produce the pleasant odors we associate with particular foods. In fact, much of what we perceive as a taste may actually be an odor. Radiation therapy of the head or neck, Parkinson disease, and Alzheimer disease often lead to olfactory losses and less interest in eating.

Mastication

Food is broken into smaller particles by biting and chewing.[1] Digestive enzymes act only on the surface of food particles; therefore chewing, which enlarges the surface area available for enzyme action, is an important step in preparing food for digestion. Chewing also produces finer particles, easing the passage of the food mass down the esophagus and into the stomach. Chewing prepares fiber-containing foods such as fruits, vegetables, and whole grains for digestion. Decayed or missing teeth or poorly fitting dentures make eating difficult. **Gingivitis** and other diseases of the gums and supporting structures of the teeth can result in mouth pain, infection, or further tooth loss, thereby limiting food intake and contributing to malnutrition.

Chemical Digestion

In the mouth, three pairs of salivary glands—parotid, submaxillary, and sublingual—produce a watery fluid containing salivary amylase. This enzyme is specific for starch. The salivary glands also secrete mucus to lubricate and bind the food particles together. The gastrointestinal tract secretes large amounts of digestive fluids (Table 2.1). Saliva secretion alone ranges from 800 to 1500 mL a day. Food remains in the mouth for only a short time; thus starch digestion here is brief. However, when salivary amylase binds to starch molecules, it becomes resistant to inactivation by gastric acid, thereby allowing the breakdown of starch to continue in the stomach.[3] A second digestive enzyme released in saliva is lingual lipase, which begins the digestion of fat.

Salivary secretions have other important functions in addition to initiating digestion. They moisten the food particles so they bind together to form a bolus that moves easily down the esophagus, and they lubricate and cleanse the teeth and tissues of the mouth, destroying harmful bacteria and neutralizing any toxic substances entering the mouth. Inadequate secretion leads to the condition known as *dry mouth*. Everyone experiences occasional dry mouth when nervous, upset, or under stress. However, prolonged drastic reduction in the production of saliva leads to swallowing problems as individual particles of food get separated in the esophagus. Infections and ulcers in the mouth, along with tooth decay, are other outcomes of extreme dry mouth, usually referred to as *xerostomia*. Radiation therapy that damages the salivary glands and conditions such as diabetes, Parkinson disease, and autoimmune deficiency diseases can lead to xerostomia. Various medications for management of cardiac failure, hypertension, depression, or chronic pain contribute to dry mouth.[6]

TABLE 2.1 Comparative pH Values and Approximate Daily Volumes of Gastrointestinal Secretions

Secretion	pH	Daily Volume (mL)
Salivary	6.0–7.4	1000
Gastric	1.0–3.5	1500
Pancreatic	8.0–8.3	1000
Small intestinal	7.5–8.0	1800
Brunner gland (bicarbonate)	8.0–8.9	200
Bile	7.5–7.8	1000
Large intestinal	7.5–8.0	200
Total		6700

Modified from Guyton AC, Hall JE: *Textbook of medical physiology,* ed 10, Philadelphia, 2000, WB Saunders.

Swallowing

Swallowing involves both the mouth and the **pharynx**. It is intricately controlled by the swallowing center in the brainstem, and damage to these nerves through radiation therapy, aging, or disease makes swallowing difficult. As illustrated in Fig. 2.5, the tongue initiates a swallow by pressing the food upward and backward against the palate. From this point on, swallowing goes forward as an involuntary reflex and, once begun, cannot be interrupted. Swallowing occurs rapidly, taking less than 1 second, but in that time the larynx must close to prevent food from entering the trachea and moving into the lungs and the soft palate must rise to prevent food from entering the nasal cavity. Patients must never be fed in a supine position because it increases the risk of food aspiration into the lungs.

Esophagus

The esophagus is a muscular tube that connects the mouth and throat with the stomach and serves as a channel to carry the food mass into the body. Functionally, it has the following three parts[1]:

1. *Upper esophageal sphincter (UES):* The UES controls the entry of the food **bolus** into the esophagus. Between swallows the UES muscle is closed. Within 0.2 to 0.3 seconds after a swallow, nerve stimuli open the sphincter to receive the food mass.

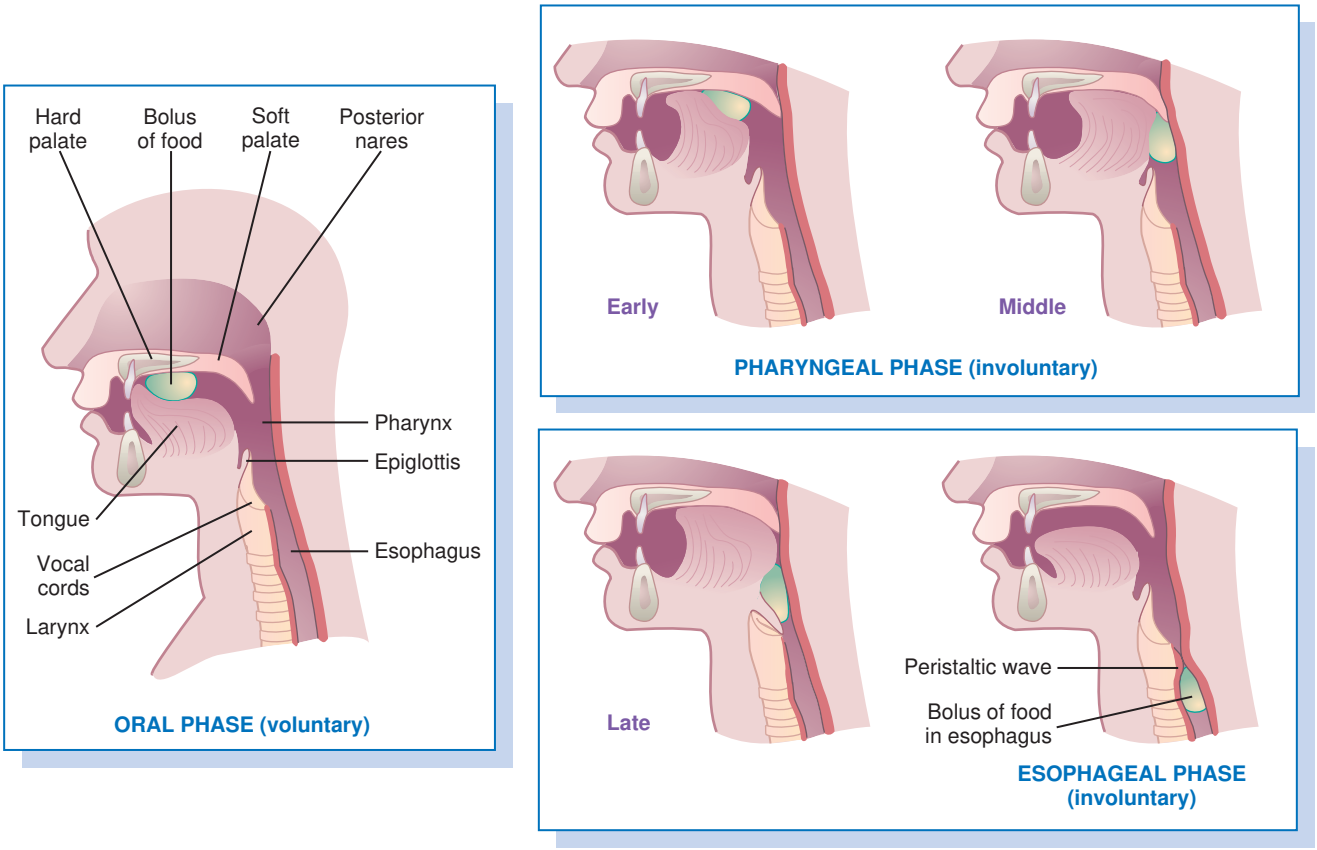

FIG. 2.5 Swallowing is a highly coordinated task directed by a special nerve center in the hypothalamus. (From Mahan KL, Escott-Stump S, editors: *Krause's food, nutrition, and diet therapy,* ed 12, Philadelphia, 2008, Saunders.)

2. *Esophageal body:* The mixed bolus of food immediately passes down the esophagus, moved along by peristaltic waves controlled by nerve reflexes. Degenerative changes in the muscles or nerves lower the intensity and frequency of the peristaltic waves, slowing passage down the channel. Diabetic neuropathy is one cause of such problems. Associated pain and discomfort can lower food intake, resulting in unwanted weight loss. Gravity aids the passage of food down the esophagus when the person eats in an upright position.
3. *Lower esophageal sphincter (LES):* The LES controls the movement of the food bolus into the stomach. When the LES muscles maintain excessively high muscle tone, they fail to open after a swallow, preventing the passage of food into the stomach. This condition is called *achalasia,* meaning "unrelaxed muscle." (See Chapter 20 for a discussion of this condition.)

KEY TERMS

Gingivitis
Red, swollen, bleeding gums, often caused by accumulation of bacterial plaque on the teeth.

Pharynx
Throat.

Bolus
Rounded mass of food formed in the mouth and ready to be swallowed.

Entry Into the Stomach

At the point of entry into the stomach, the gastroesophageal constrictor muscle relaxes to allow the food to pass and then contracts quickly to prevent regurgitation of the acidic stomach contents back into the esophagus. When this mechanism fails and regurgitation occurs, the resulting discomfort is called *heartburn*. The medical name for this condition is gastroesophageal reflux disease (GERD). GERD damages the tissues of the esophagus, which are unprotected from the destructive effects of gastric acid. Mucus secreted by cells in the stomach wall protects those tissues from the harsh effects of this acid. Obesity, overeating, physical inactivity, smoking, and certain medications contribute to GERD. According to national health care data, 7 million Americans per year are diagnosed with GERD and this condition was responsible for more than 300,000 visits to an emergency room.[7] The increasing prevalence of obesity likely contributes to these statistics.

STOMACH: STORAGE AND INITIAL DIGESTION

Motility

The major parts of the stomach are described in Fig. 2.6. Muscles in the stomach wall have three motor functions: (1) storage, (2) mixing, and (3) controlled emptying. As the food mass enters the stomach it rests against the stomach walls, which stretch to store as much as 1 L of food and fluid. Local tonic muscle waves increase their kneading and mixing actions to move the mass of food and secretions toward the pyloric valve at the **distal** end of the stomach. Over time, waves of peristaltic contractions reduce the

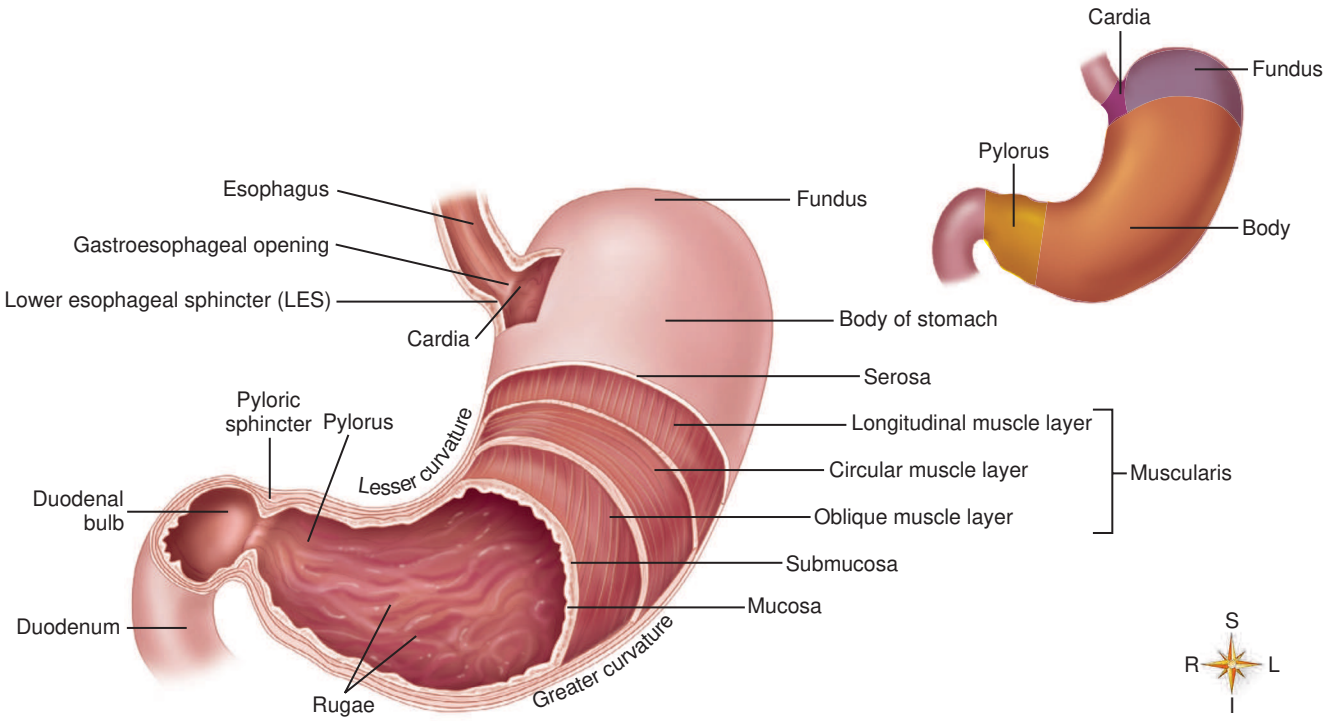

FIG. 2.6 Stomach. The pyloric sphincter controls passage of the food mass from the stomach into the duodenum, the upper section of the small intestine. See also the five layers of muscle found in the stomach wall. (From Thibodeau GA, Patton KT: *Anatomy & physiology,* ed 7, St. Louis, 2010, Mosby.)

food mass to the semifluid chyme. Finally, with each wave, small amounts of chyme pass through the pyloric sphincter into the **duodenum**. The pyloric sphincter periodically constricts and relaxes to control the rate of emptying. The highly acid chyme must be released slowly enough to allow it to be buffered by the alkaline secretions of the small intestine. The caloric density of a meal, along with its volume and composition, influences the rate of stomach emptying. The speed at which food moves from the gastroesophageal sphincter to the distal end of the stomach and into the small intestine influences food intake, as messages to the brain signaling the arrival of food in the small intestine bring about the release of gastrointestinal hormones that induce feelings of satiety.

Chemical Digestion

Types of Secretions

Secretions produced in the stomach include acid, mucus, and enzymes, as follows:

- *Acid:* Hydrochloric acid creates the acidic environment necessary for certain digestive enzymes to work. For example, a pH of 1.8 to 3.5 is needed for the enzyme pepsin to act on protein; at a pH of 5.0 or greater, there is little or no pepsin activity.
- *Mucus:* This **viscous** secretion protects the stomach lining from the eroding effect of the acid. Mucus also binds and mixes the food mass and helps move it along.
- *Enzymes:* The major enzyme in the stomach is pepsin, which begins the breakdown of protein. Pepsin is secreted in the form of pepsinogen and activated by hydrochloric acid. The stomach also produces a small amount of gastric lipase (tributyrinase) that acts only on butterfat and has a relatively minor role in overall digestion. Children have a gastric enzyme called *rennin* (not to be confused with the renal enzyme renin) that aids in the coagulation of milk. Coagulation of milk proteins, changing them from a liquid to a semisolid (as occurs when egg white is heated), slows the rate of stomach emptying, ensuring gradual passage of material to the small intestine. Rennin is absent in adults.

Control of Secretions

Stimuli for the release of gastric secretions come from two sources:

1. *Nerve stimuli* are produced in response to the visual and chemical senses, the presence of food in the gastrointestinal tract, and emotional distress. Anger and hostility increase gastric secretions; fear and depression lower secretions and inhibit blood flow to the region and gastric motility.
2. *Hormonal stimuli* are produced when food enters the stomach. Certain food components, especially caffeine, alcohol, and meat extracts, cause the mucosal cells of the **antrum** to release the local gastrointestinal hormone **gastrin**. Gastrin, in turn, stimulates the secretion of hydrochloric acid. When the pH falls to less than three, a feedback mechanism halts the release of gastrin, preventing accumulation of excess acid.[3] A second gastrointestinal hormone, **enterogastrone**, produced in the mucosa of the duodenum, also prevents excessive gastric response by inhibiting secretion of hydrochloric acid and pepsin and slowing gastric motility. (The Evidence-Based Practice box, "Why Do Some Older Adults With Recommended Intakes of Vitamin B_{12}–Containing Foods Become Deficient: Low Secretion of Gastric Acid" describes a problem that occurs when secretion of gastric acid is inadequate.)

EVIDENCE-BASED PRACTICE

Why Do Some Older Adults With Recommended Intakes of Vitamin B_{12}–Containing Foods Become Deficient: Low Secretion of Gastric Acid

Identify the problem: Poor vitamin B_{12} status is observed among many older adults despite their liberal intakes of meat and other animal foods supplying this vitamin.

Review the evidence: Older adults could develop a vitamin B_{12} deficiency because they no longer produce intrinsic factor, the protein carrier secreted by the gastric mucosa and required for vitamin B_{12} absorption. To confirm this hypothesis, older adults who were vitamin B_{12} deficient were given labeled doses of crystalline vitamin B_{12}, one dose with intrinsic factor and one without intrinsic factor. Absorption was evaluated by the later appearance of labeled vitamin B_{12} in the urine. It was expected that the dose given without intrinsic factor would remain unabsorbed. Much to the surprise of the researchers, many of these older adults absorbed the vitamin-only test dose—so why were they deficient? Further studies revealed it was not a lack of intrinsic factor, but rather a lack of gastric acid. It is estimated that 50% of older adults secrete very low amounts of hydrochloric acid, and a strongly acid environment is required in the stomach to activate pepsinogen to pepsin, the enzyme needed to break down dietary protein. When animal proteins are not broken down completely, their vitamin B_{12} is not released for absorption and is lost in the feces.

Implement the findings: Crystalline vitamin B_{12} added to fortified breads, cereals, juices, and vitamin supplements is not bound to protein and is not dependent on an acid environment for absorption. Older adults should be encouraged to include a vitamin B_{12}–fortified food in their meal pattern several times a week to ensure an adequate body supply. In addition, we have learned that vitamin B_{12} in milk and dairy products is fairly well absorbed, even if gastric acid secretion is limited, because these proteins are more easily digested than those found in meat, poultry, and fish. For older individuals with adequate acid secretion, meat is an excellent source of vitamin B_{12}.

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Russell RM, Baik H, Kehayias JJ: Older men and women efficiently absorb vitamin B_{12} from milk and fortified bread, *J Nutr* 131:291, 2001.

KEY TERMS

Distal
Away from the point of origin.

Duodenum
The first section of the small intestine entered by food passing through the pyloric valve from the stomach.

Viscous
Sticky.

Antrum
Lower section of the stomach.

Gastrin
Hormone secreted by mucosal cells in the antrum of the stomach that stimulates the parietal cells to produce hydrochloric acid.

Enterogastrone
Hormone produced in the mucous membrane of the duodenum that inhibits gastric acid secretion and motility.

SMALL INTESTINE: MAJOR DIGESTION, ABSORPTION, AND TRANSPORT

Motility

Intestinal Muscle Layers

Review the complex structure of the intestinal wall pictured in Fig. 2.2. Coordination of intestinal motility is accomplished by three layers of muscle: (1) the thin layer of smooth muscle embedded in the mucosa with fibers extending up into the villi, (2) the circular muscle layer, and (3) the longitudinal muscle lying next to the outer serosa.

Types of Intestinal Muscle Action

Under the control of the intramural nerve plexus, wall-stretch pressure from food or hormonal stimuli produces muscle action of the following two types:

1. *Propulsive movements:* Peristaltic waves from contractions of the deep circular muscles propel the food mass slowly forward. Fiber and other indigestible materials from plant foods aid this process, providing bulk for the action of these muscles. The presence of food or irritants brings about long sweeping waves over the entire intestine.
2. *Mixing movements:* Local constrictive contractions occurring every few centimeters mix and chop the food particles in the semiliquid chyme. General tonic contractions ensure continuous passage and valve control, and periodic, rhythmic contractions mix and propel the food mass forward, facilitating ongoing digestion and future absorption.

Chemical Digestion

Major Role of the Small Intestine

In comparison to other sections of the gastrointestinal tract, the small intestine carries the major burden of chemical digestion. It secretes several enzymes, each specific for carbohydrate, fat, or protein, and is assisted by other enzymes entering from the pancreas. The small intestine acts as a regulatory center sensing the nutrient content, pH, and **osmolarity** of its contents and controls enzyme secretion accordingly.[3]

Types of Secretions

The following four types of secretions complete this final stage of chemical digestion:

1. *Enzymes:* Specific enzymes act on specific macronutrients to bring about their final breakdown to forms the body can absorb and use (Table 2.2).
2. *Mucus:* Glands located at the entrance to the duodenum secrete large amounts of **mucus**. As in the stomach, mucus protects the

TABLE 2.2 Summary of Macronutrient Digestion

Nutrient	Mouth	Stomach	Small Intestine
Carbohydrate	Salivary amylase breaks down starch to dextrins		Pancreatic amylase breaks down starch to disaccharides: lactose, sucrose, and maltose. Disaccharides are broken down to monosaccharides. Lactase breaks down lactose to glucose and galactose. Sucrase breaks down sucrose to glucose and fructose. Maltase breaks down maltose to glucose and glucose.
Protein		Pepsin and HCl break down protein to polypeptides	Trypsin breaks down proteins and polypeptides to dipeptides. Chymotrypsin breaks down proteins and polypeptides to dipeptides. Carboxypeptidase breaks down polypeptides and dipeptides to amino acids. Aminopeptidase breaks down polypeptides and dipeptides to amino acids. Dipeptidase breaks down dipeptides to amino acids.
Fat	Lingual lipase has a minor role in beginning fat digestion	Tributyrinase breaks down tributyrin (butterfat) to glycerol and fatty acids	Bile emulsifies fat. Pancreatic lipase breaks down fat to glycerol, diglycerides, monoglycerides, and fatty acids.

intestinal mucosa from irritation and digestion by the entering highly acidic chyme. Other cells along the inner intestinal wall, when touched by the moving food mass, secrete mucus to protect the mucosal tissues from abrasion.

3. *Hormones:* When signaled by the presence of acid in the food mass entering from the stomach, mucosal cells in the upper part of the small intestine produce the local gastrointestinal hormone **secretin**. Secretin, in turn, stimulates the pancreas to send alkaline pancreatic juices into the duodenum to buffer the acidic chyme. The intestinal mucosa in the upper duodenum could not withstand the high acid of the entering chyme without the neutralizing action of the bicarbonate-containing pancreatic juice.
4. *Bile:* Bile emulsifies fat and facilitates its digestion. Bile is produced in the liver as a dilute watery solution and is then concentrated and stored by the gallbladder. When fat enters the duodenum, the local gastrointestinal hormone **cholecystokinin (CCK)** is secreted by glands in the intestinal mucosa and stimulates the gallbladder to contract and release bile. By means of the *enterohepatic circulation* (Fig. 2.7), molecules of bile are reabsorbed and returned to the liver and gallbladder to be used over and over again. CCK also acts on the pancreas to stimulate the release of enzymes that break down fats, proteins, and carbohydrates.

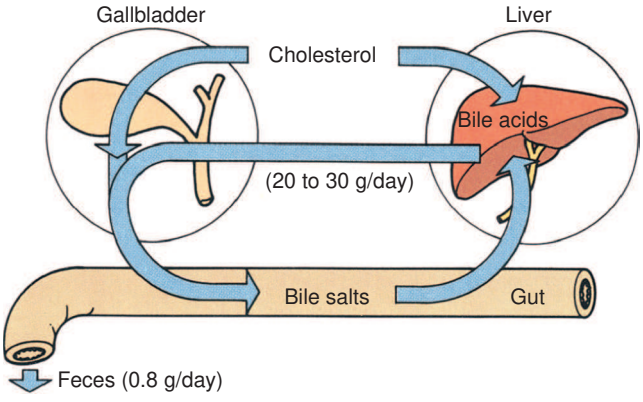

FIG. 2.7 Enterohepatic circulation of bile salts. Bile salts are reabsorbed from the small intestine and returned to the liver and then the gallbladder to be used again and again.

End Products of Digestion

When digestion of the macronutrients is complete, the simplified end products (Table 2.3) are ready for **absorption**. At times, undigested nutrients remain in the small intestine,[8] causing discomfort or distress. When individuals lack the digestive enzyme lactase, the disaccharide lactose remains in the small intestine and attracts large amounts of fluid, resulting in abdominal pain and diarrhea, nausea, and flatulence. (This condition and its clinical management are discussed later in this chapter.)

Absorption

Surface Structures

Viewed from the outside, the small intestine appears smooth, but the inner surface is quite different. As in Fig. 2.8 the following three types of convolutions and projections greatly expand the absorbing surface:

1. *Mucosal folds:* Large folds similar to hills and valleys in a mountain range are easily seen with the naked eye.
2. *Villi:* Fingerlike projections on these folds called **villi** can be seen through a simple compound microscope.
3. *Microvilli:* These extremely small projections on each villus can be seen only with an electron microscope. The array of **microvilli** covering the edge of each villus is called the *brush border* because it resembles bristles on a brush. Each villus has an ample network of blood capillaries for the absorption of monosaccharides and amino acids, and a central lymph vessel called a *lacteal* for the absorption of fatty acids.

TABLE 2.3 End Products of Digestion

Macronutrient	End Products
Carbohydrate	Glucose, fructose, and galactose (monosaccharides)
Fat	Fatty acids, monoglycerides, diglycerides, and glycerol
Protein	Amino acids, dipeptides

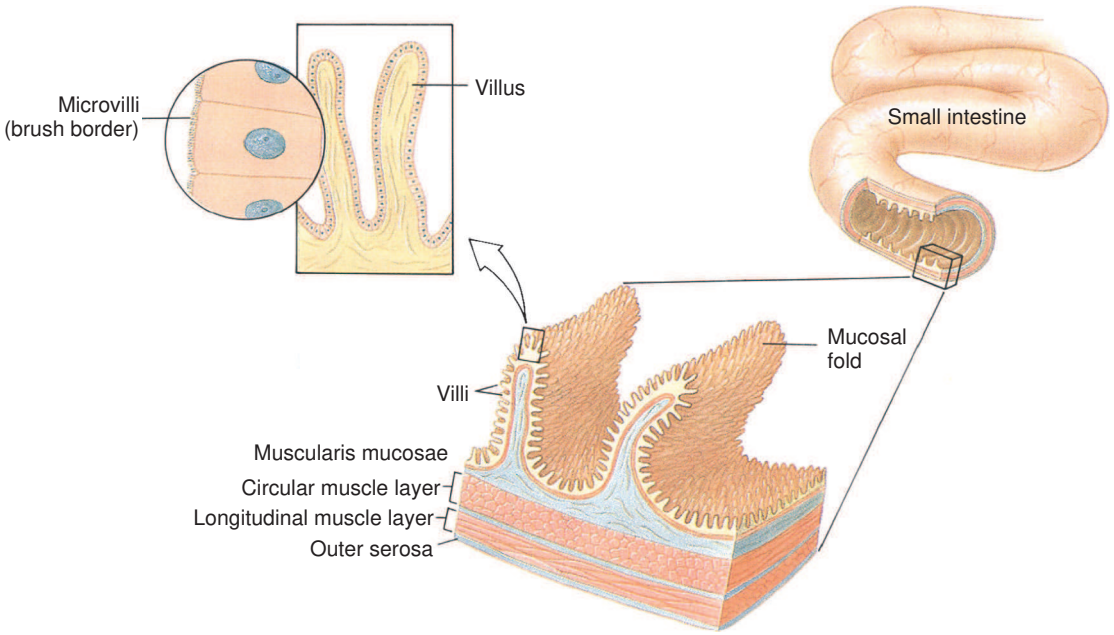

FIG. 2.8 Absorbing structures of the intestine. Note the structures of the intestinal mucosa that increase the surface area for absorption: mucosal folds, villi, and microvilli. (Courtesy Medical and Scientific Illustration.)

The mucosal folds, villi, and microvilli together increase the inner surface area of the small intestine approximately 1000 times over that of the outside covering.[1] These specialized structures, plus the contracted length of the small intestine—630 to 660 cm (21 to 22 feet)—produce a tremendously large surface area to capture and absorb nutrients. This absorbing surface, if stretched out flat, would be as large as a tennis or basketball court. The small intestine is one of the most highly developed organs in the body, making possible its tremendous absorptive capacity for food and fluid (Table 2.4).

KEY TERMS

Osmolarity
Number of millimoles of liquid or solid in a liter of solution; used to describe the concentration of body fluids.

Mucus
Viscous fluid secreted by mucous membranes and glands, containing mucin (a glycoprotein), inorganic salts, and water.

Secretin
Hormone produced in the mucous membrane of the duodenum in response to the entrance of acid contents from the stomach; stimulates the flow of pancreatic juices containing digestive enzymes and bicarbonate to neutralize the acid.

Cholecystokinin (CCK)
A hormone secreted by the mucosa of the duodenum in response to the presence of fat; causes the gallbladder to contract and propel bile into the duodenum where needed to emulsify the fat.

Absorption
Transport of nutrients from the lumen of the intestine across the intestinal wall into the blood (glucose and amino acids) or the lymph (fatty acids).

Villi
Fingerlike projections covering the mucosal surface of the small intestine.

Microvilli
Minute vascular structures protruding from the villi that form a "brush border" and facilitate absorption of nutrients.

Mechanisms of Absorption

Absorption of the nutrients dispersed in the water-based solution entering the small intestine involves several transport mechanisms. The particular transport mechanism used depends on the nutrient and the prevailing electrochemical fluid pressure gradient; these are described as follows:

- *Passive diffusion and osmosis:* When there is no opposing fluid pressure, molecules small enough to pass through the capillary membranes diffuse easily into the villi (Fig. 2.9). High concentrations of nutrients waiting to move into the capillaries where nutrient

TABLE 2.4 Volume of Fluid Absorbed Daily by the Gastrointestinal System

Substance	Intake (L)	Intestinal Absorption (L)	Elimination (L)
Food ingested	1.5		
Gastrointestinal secretions	8.5		
TOTAL	10.0		
Fluid absorbed in small intestine		9.5	
Fluid absorbed in large intestine (colon)		0.4	
TOTAL		9.9	
Feces			0.1

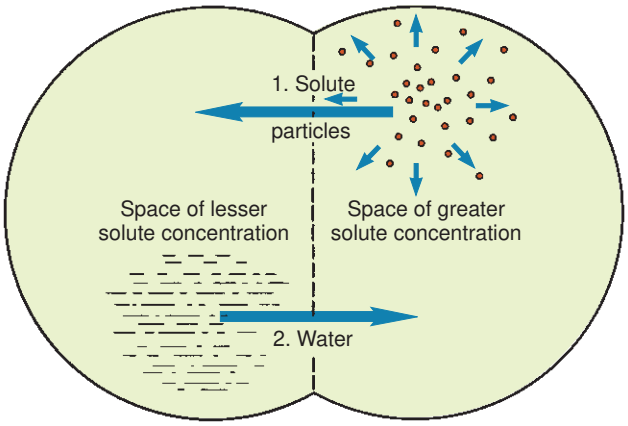

FIG. 2.9 Movement of molecules, water, and solutes through osmosis and diffusion.

concentrations are low create an electrochemical gradient and osmotic pressure that promote absorption.[1]

- *Facilitated diffusion:* Even when the pressure gradient supports absorption, some molecules may be too large to pass easily through the membrane pores and need assistance. Specific proteins located in the membrane facilitate passage by carrying the nutrient across the membrane.
- *Energy-dependent active transport:* Nutrients must cross the intestinal membrane to reach hungry cells even when the flow pressures are against them. Such active work requires extra energy along with a pumping action. A special membrane protein carrier, coupled with the active transport of sodium, assists in the process. The energy-requiring, sodium-coupled transport of glucose is an example of this action. The enzyme sodium/potassium-dependent adenosine triphosphatase (Na^+/K^+-ATPase) in the cell membrane supplies the energy for the pump.
- *Engulfing* ***pinocytosis***: At times, fluid and nutrient molecules are absorbed by pinocytosis. When the nutrient particle touches the absorbing cell membrane, the membrane dips inward around the nutrient, surrounds it to form a vacuole, and then engulfs it. The nutrient is then conveyed through the cell cytoplasm and discharged into the circulation. Smaller whole proteins and fat droplets are absorbed through pinocytosis (Fig. 2.10).

Routes of Absorption

After crossing the intestinal wall, the water-soluble monosaccharides and amino acids enter the portal blood and travel to the liver and other tissues. Fat, which is not water soluble, follows a different route. Fats packaged in a bile complex called a *micelle* (described in detail in Chapter 4) move into the cells of the intestinal wall, where they are processed into human lipid compounds and joined with a carrier protein. These **lipoproteins**, called *chylomicrons,* flow into the lymph, empty into the cisterna chyli (the central abdominal collecting vessel of the lymphatic system), travel upward into the chest through the thoracic duct, and finally flow into the venous blood at the left subclavian vein. The chylomicrons are rapidly cleared from the blood by a special fat enzyme called *lipoprotein lipase.*

Exceptions to this route of fat absorption are the shorter-chain fatty acids with 10 or fewer carbons. Because these short-chain fatty acids are water soluble, they can be absorbed directly into the blood along with the carbohydrate and protein breakdown products. However, most dietary fats are made of long-chain fatty acids that are not water soluble and must take the lymphatic route.

KEY TERMS

Pinocytosis
Means of nutrient absorption by which the molecule is engulfed by the cytoplasm of the receiving cell.

Lipoproteins
Complexes of fat with protein that transport lipids in the blood.

COLON (LARGE INTESTINE): FINAL ABSORPTION AND WASTE ELIMINATION

Role in Absorption

Within a 24-hour period, approximately 1500 mL of remaining food mass leaves the **ileum**, the last section of the small intestine, and enters the cecum, the pouch at the entrance to the **colon**. Passage is controlled by the ileocecal valve. Normally the valve remains closed, but each peristaltic wave relaxes the valve muscle, squirting a small amount of remaining chyme into the cecum. This action holds the food mass in the small intestine long enough to ensure maximal digestion and absorption. Nutrients and other materials, including electrolytes, minerals, vitamins, intestinal bacteria, and nondigestible residue, remain in the chyme delivered to the large intestine.

Water Absorption

The main task remaining for the colon is the absorption of water. The capacity of the colon to absorb water is vast, with a net daily maximum

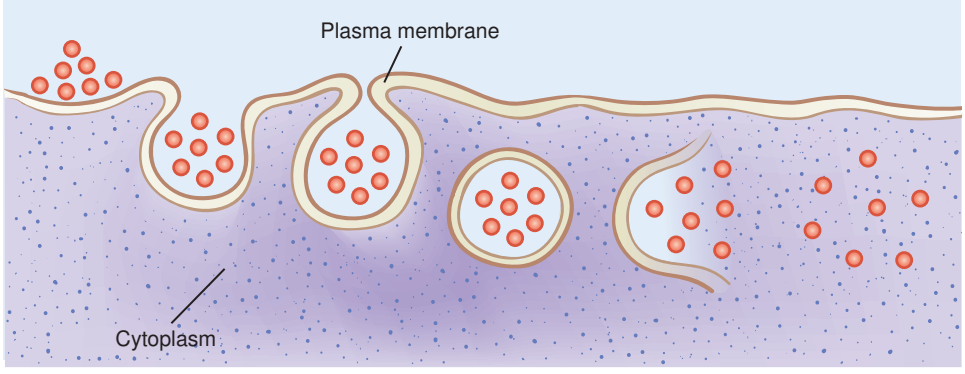

FIG. 2.10 Pinocytosis, the engulfing of large molecules by the cell. (From Nix S: *Williams' basic nutrition and diet therapy,* ed 13, St. Louis, 2009, Mosby.)

of 5 to 8 L.[1] Normally, from 1.0 to 1.5 L is received from the ileum, and 95% of that is absorbed (review Table 2.4).

Much of the water in the chyme (350 to 400 mL) is absorbed in the first half of the colon. Only 100 to 150 mL remains to form the feces.[1] Absorption of water in the colon is important in the regulation of water balance and the elimination of fecal waste. When the chyme first enters the colon, it is a semiliquid, but water absorption during passage changes it to the semisolid nature of normal feces.

The amount of water absorbed in the colon depends on motility and rate of passage. Poor motility and a slow passage rate, often associated with low dietary fiber and low fecal mass, allow greater absorption of water, resulting in hard stools that are difficult to pass, and constipation. Excess motility and too-rapid passage limit the absorption of water and important electrolytes, producing a high volume of loose, watery stool (diarrhea). Diarrhea can result from disease; microbial infection as in foodborne illness; or large amounts of undigested sugar, such as lactose, that exert osmotic pressure and hold vast amounts of fluid. Severe or extended diarrhea leads to dehydration and serious loss of electrolytes.

Mineral Absorption

Sodium and other electrolytes are absorbed from the colon. Intestinal absorption exerts major control on body content of many minerals, and much of our dietary intake is unabsorbed and excreted in the feces. Up to 90% of the calcium and iron in the food we eat is not absorbed. The proportion of a mineral intake that is generally absorbed is an important aspect of nutrient balance and must be considered in dietary evaluation.

Vitamin Absorption

Conditions in the gastrointestinal tract influence the absorption of vitamins. When gastric acid secretion is lower than normal, vitamin B_{12} is less efficiently released from animal tissues and is lost in the feces. Conversely, colonic bacteria synthesize vitamin K and biotin, which are actively absorbed and serve as a major source of the body's supply.

Role of Colon Microflora

At birth the colon is sterile, but intestinal bacteria acquired through passage down the birth canal and infant feeding promote the growth and diversity of particular species. More than 1500 species of bacteria have been identified in the human intestine, and adult composition is usually established by 3 years of age. The microbial population of the gastrointestinal tract is approximately 10 times the total number of cells in the human body.[9] Individuals differ in type and number of bacteria based on genetics, diet, and physical environment. A plant-based diet supports species associated with positive health; use of antibiotics can bring about permanent changes in the microbial community. Differing bacteria acquired through vaginal versus cesarean delivery and breast versus formula feeding may influence health status throughout life.[10] Many bacteria ingested with food do not survive the extreme acid environment in the stomach.

Bacteria from the colon make up approximately one-third of fecal weight[1] and influence the color and odor of the stool. Colonic bacteria acting on **bilirubin** produce bile pigments, giving the stool its characteristic brown color; thus, when bile flow is hindered, the feces become clay colored or white. The characteristic odor of the stool comes from amines, especially indole and skatole, formed by the action of bacterial enzymes on amino acids.

Gastrointestinal microflora have many roles. Particular microorganisms produce bothersome gas or increase the risk of gastrointestinal disease. Other species make important and positive contributions to health. (We discuss these relationships in the following sections.)

Excessive Gas Production

Colonic bacteria are major contributors to gas production, including carbon dioxide (CO_2), molecular hydrogen (H_2), methane, and sometimes hydrogen sulfide. Gas formation is a normal occurrence in the gastrointestinal tract and, though harmless, is distressing when it causes pain or embarrassment. Intestinal gas, or flatus, can be exaggerated by specific foods or physiologic circumstances in the person eating them.

Usually, gas is produced by the bacterial fermentation of undigested or incompletely absorbed carbohydrate. Humans lack the enzymes necessary to digest the oligosaccharides raffinose and stachyose found in legumes and cause the intestinal gas associated with these foods. Certain starches and fibrous materials in whole grains, fruits, and vegetables are resistant to pancreatic amylase and cannot be broken down and absorbed. Individuals should increase their intakes of fiber gradually to allow a more comfortable adjustment and prevent gastrointestinal distress.

Excessive gas has social implications. Methane, CO_2, and H_2 are odorless, but hydrogen sulfide carries a striking odor. Hydrogen sulfide most often arises from cruciferous vegetables (cabbage, cauliflower, or broccoli) or large amounts of beer, all high in sulfur. Various over-the-counter products claim to reduce the formation of gas or eliminate gaseous odors, but all have limitations. Individuals should check with their physician before using such preparations.[11] (See the Complementary and Alternative Medicine [CAM] box, "Bismuth and Certain Herbs: A Dangerous Combination," for cautions.)

Waste Elimination

Fully formed and ready for elimination, normal feces are approximately 75% water and 25% solids.[1] Solids include fiber, bacteria, inorganic matter such as minerals, a small amount of fat and its derivatives, some mucus, and sloughed-off mucosal cells.

The mass of food residue now slows its passage. Approximately 4 hours after a meal is eaten, food enters the cecum, having traveled the entire length of the small intestine (630 to 660 cm [21 to 22 ft]).

KEY TERMS

Ileum
The distal section of the small intestine that connects with the colon.

Colon
The large intestine extending from the cecum to the rectum.

Bilirubin
A reddish bile pigment resulting from the degradation of heme by reticuloendothelial cells in the liver; a high level in the blood produces the yellow skin symptomatic of jaundice.

COMPLEMENTARY AND ALTERNATIVE MEDICINE (CAM)

Bismuth and Certain Herbs: A Dangerous Combination

Bismuth-containing medications such as Pepto-Bismol are used to ease gas and bloating. Bismuth also binds with the odor-causing sulfur compounds found in intestinal gas and helps to reduce odor and embarrassment. However, when combined with gingko, garlic, ginger, or ginseng, bismuth and these herbs act as anticoagulants. Individuals should consult their physician before using such a combination.

Bonci L: *American Dietetic Association guide to better digestion,* Hoboken, NJ, 2003, John Wiley & Sons.

Approximately 8 hours later, it reaches the sigmoid colon, having traveled an additional 90 cm (3 ft) through the large intestine. In the sigmoid colon, the residue descends still more slowly toward its final destination, the rectum (review Fig. 2.1 to follow its passage).

The rectum begins at the end of the large intestine immediately past the descending colon and ends at the anus. Feces are usually stored in the descending colon; however, when it becomes full, feces pass into the rectum, presenting the urge to defecate. Anal sphincters under voluntary control regulate the elimination of feces from the body. As much as 25% of a meal may remain in the rectum for up to 72 hours.

GASTROINTESTINAL FUNCTION AND CLINICAL APPLICATIONS

Chronic Gastrointestinal Distress

Most of the time the gastrointestinal tract is a smoothly working system that allows us to enjoy the food we eat while effectively handling digestion, absorption, and the elimination of waste. However, abdominal pain or bloating, early satiety, post-meal discomfort, nausea, or vomiting are regular occurrences for some individuals, and for more than half, diagnostic tests fail to identify a disease or structural explanation.[12] This situation, referred to as *functional* ***dyspepsia***, adds significantly to health care costs and loss of productivity at the workplace and impacts on vitality and quality of life.[13] Anxiety, depression, emotional stress, various prescription medications, certain foods, and chronic disease influence gastrointestinal function and may contribute to symptoms in particular individuals.

We need to listen carefully when people tell us about gastrointestinal problems that limit their enjoyment of food or food selection. Health literacy should include perspectives on over-the-counter drugs or remedies claiming to enhance digestion, inappropriate laxatives, or procedures such as colonic irrigation. Chronic digestive problems demand medical assessment and intervention. (See the Perspectives in Practice box, "Help Your Digestive System Work for You," for practices that support optimal digestive function.)

Lactose Intolerance

Lactose intolerance is a digestive problem related to the inability to digest and absorb lactose. It stems from a deficiency of lactase, the digestive enzyme in the microvilli of the small intestine that breaks lactose into the simple sugars glucose and galactose, necessary for absorption. When undigested lactose remains in the small intestine and colon, it attracts large amounts of water and is fermented by resident bacteria, producing pain, diarrhea, bloating, and gas. Congenital intolerance to lactose is rare; infants usually produce enough lactase to digest the large amounts of lactose in mother's milk. However, adult-onset lactase deficiency is the normal physiologic pattern. It is estimated that at least 80% of Blacks, Asians, and individuals of Mediterranean or Middle Eastern descent are lactase deficient as compared with 20% of whites.[14] In many parts of the world lactose was not present in the diet after weaning; therefore this enzyme was no longer needed. A dairy-based culture in various regions of Europe likely contributed to higher lactase activity among whites.[15]

Individuals with lactose intolerance vary in their ability to digest lactose, although most can tolerate 6 g, equal to ½ cup of milk. Individuals who experience symptoms when ingesting one or two tablespoons of milk likely have another existing condition that is the root cause of the problem.[16] In general, symptoms will not occur with doses of 12 g of lactose (the amount of lactose found in 1 cup of milk), especially if consumed with a meal. Clinical protocols to establish lactose maldigestion have often directed the patient to consume one quart of milk at a single sitting, leading to an overdiagnosis of intolerance.[16] Maldigestion of lactose does not mean that an individual is allergic to milk or dairy foods, although both conditions are sometimes present in the same person. A true milk allergy is caused by the protein in milk, not the lactose.[14]

Other conditions can cause or worsen symptoms after eating foods that contain lactose. Irritable bowel syndrome, celiac disease, cystic fibrosis, or other disorders that damage the intestinal mucosa can interfere with secretion of lactase, and medical diagnosis is often needed to confirm the basis of the malabsorption. Viral infections with prescription of antibiotics can cause temporary lactose intolerance. The identification of genes associated with continuing lactase secretion has enabled genetic testing to confirm true lactose intolerance.[17]

KEY TERMS

Dyspepsia
Gastric distress or indigestion involving nausea, pain, burning sensations, or excessive gas.

PERSPECTIVES IN PRACTICE

Help Your Digestive System Work for You

Our way of eating can either support or stress the normal function of the digestive tract. Positive practices maximize our enjoyment of food and help regulate our food intake.

- Chew your food slowly; allow time for the vapors to enter your sinus cavity and contribute to your sensation of taste.
- Take small bites; eating in a hurry and washing down large mouthfuls with liquid often lead to swallowing an excessive amount of air, causing bloating and belching.
- Wait 15 to 20 min before taking second helpings; when food moves from your stomach into your small intestine, it initiates feelings of satiety and you may find that you do not need that extra spoonful.
- Try to concentrate on pleasant thoughts or conversation while eating; emotional distress such as fear, anger, or worry often depresses the secretion of digestive enzymes and slows peristalsis, leading to gastrointestinal discomfort or upset.
- Focus on your food; try not to combine eating with watching television, completing a homework assignment, or driving to work or class.
- Enjoy the sight, smells, and anticipation of food as you prepare or serve your meal; these responses promote enzyme secretion and digestive function.
- Divide your food across the day; do not consume the majority of your kcalories at one meal; the cells lining the gastrointestinal tract derive most of their energy from the food passing through, and they require a constant supply of nutrients to meet their high metabolic demands.
- Try to eat approximately the same amount of food every day, rather than gorging 1 day and fasting the next; this supports not only efficient gastrointestinal function but also effective body weight management.

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BOX 2.1 Food Sources of Lactose

0 to 2 g Lactose
1 to 2 oz Swiss or cheddar cheese
1 oz American cheese
½ cup cottage cheese
½ cup lactase-treated milk

5 to 8 g Lactose
½ cup regular milk
½ cup white sauce
½ cup yogurt
1 cup ice cream or ice milk
2 tbsp powdered milk

Data from Bonci L: *American Dietetic Association guide to better digestion,* Hoboken, NJ, 2003, John Wiley & Sons. Images copyright 2006 JupiterImages Corporation.

Many people with lactose malabsorption do not need to follow a lactose-free diet but may include milk or other low-lactose dairy foods that will increase their intakes of calcium but avoid the digestive upset associated with lactose intolerance. These individuals may benefit from the action of species of bacteria in the small intestine and colon that produce the lactase enzyme and break down the lactose entering the large bowel. Consuming increasing amounts of lactose in the form of milk or other dairy foods can over the period of several weeks support the growth of bacterial colonies that assist in lactose digestion.[14,16] Yogurt containing active cultures also provides helpful bacteria. (Yogurt as a probiotic will be discussed later in this chapter.)

Following are suggestions on how lactose maldigesters might begin to include dairy foods in their diet[11,16]:

- *Add dairy foods gradually:* Begin with a small amount of one dairy food each day, one-quarter to one-half cup of milk or one-half ounce of cheese; include only one lactose-containing food per meal. (See Box 2.1 for food lactose content.)
- *Include lactose-containing foods with a meal or snack:* This combination slows the movement of lactose into the intestine and may reduce discomfort.
- *Choose dairy foods lower in lactose:* Use lactose-free or lactose-reduced milk. Add lactase drops such as Lactaid or Dairy Ease to milk to break down the lactose. (Acidophilus milk is not lactose free.) Aged cheeses such as cheddar or Swiss are lower in lactose than cheese spreads or other processed cheese. Lactase tablets taken right before eating can reduce gastrointestinal distress.

Lactose is also found in nondairy foods that have milk as an ingredient. Breads and other baked products, some ready-to-eat breakfast cereals, pancake and cookie mixes, instant potatoes, cream soups, hot dogs, and luncheon meats may contain lactose. Read the Nutrition Facts label, and look for the word *milk* or *whey.* (See Chapter 7 for food sources of calcium for persons who cannot tolerate any dairy foods.)

Prebiotics and Probiotics

Elie Metchnikoff, a Russian microbiologist who lived in the 19th century, speculated that fermented milk supplying microbes beneficial to colon health contributed to the long life of many peasants in his country.[18] Since then, we learned that many of the microbes populating the gastrointestinal tract promote human health and provide new tools for improving gastrointestinal and immune function and treating gastrointestinal disorders (Box 2.2). These microbes and their related food components are called *prebiotics* or *probiotics* based on their use and intestinal effects. Prebiotics are indigestible components found in food that selectively stimulate the growth of one or more species of bacteria in the colon. Probiotics are live microorganisms that bring a health benefit to the host.[18]

BOX 2.2 Colonic Bacteria Support Health in Various Ways

- Produce short-chain fatty acids that nourish the cells of the intestinal mucosa
- Deactivate carcinogens that enter the gastrointestinal tract through food
- Assist in breaking down binding substances and enabling absorption of minerals
- Prevent harmful bacteria from growing and forming colonies
- Support immune cells that attack harmful body invaders
- Synthesize biotin and vitamin K
- Assist with the regulation of hormones that control appetite and energy balance

Prebiotics

Prebiotics are indigestible carbohydrates, often oligosaccharides such as cellulose, hemicellulose, and pectin, found in plants. These fibers are resistant to the digestive secretions of the stomach and small intestine and reach the colon generally intact. Here they are fermented by the existing microflora and stimulate the growth and activity of various healthy bacteria such as *Lactobacillus* and *Bifidobacterium*. This action of prebiotics lowers the existing pH in the colon, reducing the proliferation of pathogenic bacteria such as *Clostridia* and *Helicobacter*.[19,20] All prebiotics are fibers, although not all fibers are prebiotics. Fermentation by colonic bacteria also produces short-chain fatty acids such as butyrate, that serve as preferred energy sources of the mucosal cells. Naturally occurring prebiotics include fibers found in wheat, onions, bananas, garlic, soybeans, artichokes, and asparagus, whereas other fiber derivatives are commercially produced.[21]

Health-promoting bacteria produced by prebiotics bring about various favorable actions, as follows:

- *Immune function:* Prebiotics exert a profound effect on the immune system by way of their action on microbial populations and the

protective cells lining the colon. Prebiotics influence the secretion of antibodies and other agents of the immune system to combat pathogens and potential carcinogens entering the lower gastrointestinal tract. Prebiotics support the integrity of the mucosal cells and prevent the binding of pathogens to the intestinal wall and their passage into the body.[19,21] This translation of harmful microbes across the mucosal wall has been termed "*leaky gut*" [22] and will be described further in Chapter 20.

- *Mineral absorption:* Most minerals are absorbed in the small intestine; however, the lower pH of the colon resulting from bacterial fermentation enhances the bioavailability and absorption of calcium, magnesium, and likely other minerals still remaining in the food residue.[21]
- *Normal laxation:* The fermenting action of bacteria can add to stool weight and relieve constipation, helping avoid dependence on laxatives. Prebiotics reduce the prevalence and duration of infectious and antibiotic-induced diarrhea.[19,21]

Probiotics

Probiotics can be obtained in food and dietary supplements. The most commonly used strains are *Lactobacillus*, *Bifidobacterium*, and the yeast *Saccharomyces boulardii*.[18] Lactic acid–producing bacteria have been used over the centuries to acidify and preserve foods such as cultured milk and yogurt, cheese, distilled mash, pickled cabbages, and tempeh. Probiotic cultures are available from pharmaceutical companies for clinical use, although products may not be the same even if they contain the same species. In addition, it is difficult to predict how a particular dose of living bacteria will interact with the microflora already existing in a particular individual. Moreover, clinical benefits depend on the strain, dose, duration of administration, or combination of probiotics; no single probiotic can be effective in all situations.[9] An individual's stress level may influence the composition of the microflora, whether through change in food patterns or digestive or intestinal upset.[22] Despite these uncertainties, probiotics have been used successfully to ameliorate symptoms in such gastrointestinal conditions as follows:

- Inflammatory bowel disease/Crohn disease
- Irritable bowel syndrome
- Traveler's diarrhea and
- *Clostridium difficile* infection.[20]

Two major health conditions in the United States that may benefit from intervention with probiotics are gastric cancer and obesity. A major risk factor for gastric cancer is infestation of the pathogenic bacterium *Helicobacter pylori*.[23] Probiotics seem to inhibit its growth and prevent it from burrowing into the stomach lining. (See the Focus on Culture box, "*Helicobacter pylori*: Risk Factor for African Americans and Hispanics," for more information on the prevalence of this bacterium.)

Evidence suggests that colonic microflora may have a role in the development and prevention of obesity. Obese individuals have been found to have a different population of colonic bacteria than individuals who are not obese.[24,25] Certain bacteria harvest energy by breaking down undigested carbohydrates to sugars and starches that can be absorbed and metabolized and thereby increase energy intake. Gut microflora also influence neural responses and hormones that control satiety and energy metabolism and could lead to weight gain or loss.

Although healthy bacteria have been used successfully in experimental and therapeutic interventions, safety is still a concern. Individuals with compromised immune function should not use probiotics without medical supervision, and clinicians have raised concerns about their use with critically ill patients. Contamination or the passage of a probiotic microorganism across the intestinal mucosa and into the blood could lead to sepsis in an adult who lacks normal immune response.[20]

At present no legal definitions have been formulated for the terms *prebiotic* or *probiotic*, but as dietary supplements their product labels must comply with applicable US Food and Drug Administration regulations. Accurate information relating to the exact strain or species of bacteria, dosage required for effective intervention, safety of a particular product, or product shelf life can be difficult to obtain.

FOCUS ON CULTURE

Helicobacter Pylori: Risk Factor for African Americans and Hispanics

The bacterium *H. pylori* resides in the stomach lining of nearly half of the world's population. In contrast to *Lactobacillus* and *Bifidobacterium,* which carry out functions in the human colon that contribute to good health, *H. pylori* is a known risk factor for dyspepsia, peptic ulcer, and chronic gastritis and is considered a major risk factor for some types of gastric cancer. *H. pylori* infection burrows into the cells of the mucosa and so is able to interfere with immune function and yet escape the action of gastric acid. Although a national survey reported that 31% of the US population tested positive for *H. pylori*, prevalence among African Americans and Mexican Americans was nearly twice this number. This infection may contribute to the higher incidence of gastric cancer and ulcer disease among African Americans. This bacterium also has a deleterious effect on nutrition status. Individuals who test positive for *H. pylori* have lower serum levels of retinol (vitamin A), beta carotene, and folate, despite dietary intakes equivalent to those with higher serum levels who are free of *H. pylori* infection. Among *H. pylori*–infected patients, low blood levels of ascorbic acid and vitamin B_{12} were restored to normal when their infection was eradicated. *H. pylori* status is related to socioeconomic variables, with higher rates of infection among those with less education, lower income, and poorer living conditions.

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HEALTH PROMOTION

Choosing Foods That Contain Prebiotics and Probiotics

Individuals can increase their intakes of prebiotics and probiotics by thoughtful food selection. Fruits and vegetables such as bananas, leeks, and asparagus and whole-grain oatmeal and wheat products are good sources of prebiotics.[21] Yogurt, cheese, and kefir (fermented milk prepared by adding kefir grains to cow's milk or goat's milk) all contain potentially live bacteria, but they may not be present in sufficient numbers to be effective. Some yogurts contain not only starter cultures of bacteria but also added *Lactobacillus* or *Bifidobacterium* that produce a probiotic effect. Fermented milk and yogurt marketed as functional foods and containing known strains of bacteria at probiotic levels are entering the marketplace.

METABOLISM

Following absorption, nutrients are transported to cells to provide energy or produce substances and tissues needed to sustain body functions. Metabolic activities within cells describe the total spectrum of chemical reactions associated with use of the individual macronutrients.

Carbohydrate Metabolism

Glucose is an immediate energy source for all body cells but is the preferred energy source for the brain and nervous system. Because glucose is so critical to life, its level in the blood is carefully regulated.

Sources of Blood Glucose

Both carbohydrate and noncarbohydrate molecules are sources of blood glucose, as follows:

- *Carbohydrate sources:* Three carbohydrate substances can be converted to glucose: (1) dietary starches and sugars, (2) glycogen stored in the liver and muscle, and (3) products of carbohydrate metabolism such as lactic acid and pyruvic acid.
- *Noncarbohydrate sources:* Both protein and fat are indirect sources of glucose. Certain amino acids are called *glucogenic amino acids* because they can form glucose after their amino group (NH_2^+) is removed. Approximately 58% of the protein in a mixed diet is made of glucogenic amino acids. Thus more than half of dietary protein might ultimately be used for energy if sufficient carbohydrate and fat are not available. After fats are broken down into fatty acids and glycerol, the glycerol portion (approximately 10% of the fat) can be converted to glycogen in the liver and then to glucose as needed. The formation of glucose from protein, glycerol, and carbohydrate metabolites is called **gluconeogenesis**.

Uses of Blood Glucose

Blood glucose is held within a normal range of 70 to 140 mg/dL (3.9 to 7.8 mmol/L) but is in constant flux as absorbed glucose is transported to cells for immediate use or removed from the circulation and stored as glycogen or fat. Blood glucose is used in three different ways:

- *Energy production:* The primary function of glucose is to supply energy to meet the body's constant demand. An array of metabolic pathways requiring specific and successive enzymes accomplishes this task.
- *Energy storage:* Glucose is stored in two forms: (1) glycogen, which is held in limited amounts in liver and muscle, and (2) fat (adipose tissue), which is the storage form for all excess glucose after energy demands have been met. Only a small supply of glycogen exists at any one time, and it turns over rapidly. In contrast, fat can be stored in unlimited amounts in adipose tissue and provides long-term energy stores.
- *Glucose products:* Small amounts of glucose are used to produce various carbohydrate compounds with important roles in body metabolism. Examples include deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), galactose, and certain amino acids.

These sources and uses of glucose act as checks and balances to maintain normal blood levels, adding or removing glucose as needed.

Hormonal Controls

Several hormones influence glucose metabolism and regulate blood glucose levels.

- *Blood glucose–lowering hormone:* Only one hormone—insulin—lowers blood glucose. Insulin is produced by the beta cells in the pancreas. These cells are scattered in clusters, forming "islands" in the pancreas, which gives rise to the name *islets of Langerhans* after the German scientist who first discovered them.

  Insulin lowers blood glucose by the following actions:
  - *Glycogenesis* stimulates the conversion of glucose to glycogen in the liver for energy reserve.
  - *Lipogenesis* stimulates the conversion of glucose to fat for storage in adipose tissue.
  - *Cell permeability* increases, allowing more glucose to enter the cell and be oxidized for energy.
- *Blood glucose–raising hormones:* The following hormones effectively raise blood glucose levels:
- *Glucagon* produced by the alpha cells in the pancreas acts in opposition to insulin, increasing the breakdown of liver glycogen to glucose and maintaining blood glucose levels during fasting or sleep hours. (The hydrolysis of liver glycogen to yield glucose is called **glycogenolysis**.)
- *Steroid hormones,* secreted by the adrenal cortex, release glucose-forming carbon units from protein and oppose the actions of insulin.
- *Epinephrine,* originating from the adrenal medulla, stimulates the breakdown of liver glycogen and quick release of glucose.
- *Somatostatin,* produced in the delta cells of the pancreas and in the hypothalamus, suppresses insulin and glucagon and acts as a general modulator of related metabolic activities.
- *Growth hormone (GH)* and *adrenocorticotropic hormone (ACTH),* released from the anterior pituitary gland, oppose the actions of insulin.
- *Thyroxine,* originating in the thyroid gland, increases the rate of insulin breakdown, increases glucose absorption from the small intestine, and liberates epinephrine.

Lipid Metabolism

Lipid Synthesis and Breakdown

Two organ tissues—liver and adipose tissue—participate in lipid synthesis and breakdown as partners in lipid metabolism. The fatty acids released from lipids supply body cells with concentrated fuel for energy.

Lipoproteins

Lipid-protein complexes are the transport form of lipids in the blood. An excess of blood lipoproteins produces a clinical condition called *hyperlipoproteinemia.* Lipoproteins are produced (1) in the intestinal wall after the initial absorption of dietary lipids and (2) in the liver for constant recirculation to and from cells. Because lipids and carbohydrates work together to supply the body's need for energy, they involve many of the same hormones, as follows:

- *GH, ACTH,* and *thyroid-stimulating hormone (TSH),* all coming from the pituitary gland, increase the release of free fatty acids from stored lipids when energy demands are imposed.
- *Cortisol* and *corticosterone* from the adrenal gland cause the release of free fatty acids.
- *Epinephrine* and *norepinephrine* stimulate the breakdown of lipids and release of free fatty acids.
- *Insulin* promotes lipid synthesis and storage, whereas *glucagon* has the opposite effect of breaking down lipid stores to release free fatty acids.
- *Thyroxine* stimulates release of free fatty acids and lowers blood cholesterol levels.

When fatty acids absorbed from the gastrointestinal tract are delivered to the liver and muscle in larger amounts than needed for immediate energy or synthesis of important molecules, the hormone insulin promotes the formation of triglycerides for storage in the adipose tissue. In situations of prolonged physical activity, starvation, physical

stress, or other circumstances that require energy beyond what can be supplied by available glycogen, these triglycerides are broken down and their fatty acids released. Free fatty acids are delivered to the liver to be packaged in lipoproteins for transport to cells for meeting energy needs or redeposition in adipose tissue. Muscle cells, including the heart muscle, depend on free fatty acids for their ongoing energy needs.

Protein Metabolism

Anabolism (Tissue Building)

Protein metabolism centers on the critical balance between anabolism (tissue building) and catabolism (tissue breakdown). The process of anabolism builds tissue through the synthesis of new protein, governed by a definite pattern or "blueprint" provided by DNA in the cell nucleus and calling for specific amino acids. Explicit enzymes and coenzymes along with certain hormones—GH, gonadotropins, and thyroxine—control and stimulate the building of tissue protein.

Catabolism (Tissue Breakdown)

Amino acids released from tissue breakdown are reused for making new proteins or, if not needed for protein synthesis, are broken down further and used for other purposes. The breakdown of amino acids yields two parts: (1) the nitrogen-containing group and (2) the remaining nonnitrogen residue, as follows:

1. *Nitrogen group:* The nitrogen portion is split off first, a process called **deamination**. This nitrogen can be converted to ammonia and excreted in the urine or retained for use in making other nitrogen compounds.
2. *Nonnitrogen residue:* The nonnitrogen residues are called **keto acids**. They can be used to form either carbohydrates or fats or, with the addition of a nitrogen group, can form a new amino acid. In health a dynamic equilibrium exists between anabolism and catabolism that sustains growth and maintains sound tissue.

Metabolic Interrelationships

Every chemical reaction occurring in the body is purposeful, and all are interdependent. They have two essential roles: (1) to produce energy and (2) to support the growth and maintenance of healthy tissue. The controlling agents necessary for these reactions to proceed in an orderly manner are the cell enzymes, their coenzymes (often a vitamin or mineral), and special hormones. Overall, human metabolism is an exciting biochemical process designed to develop, sustain, and protect life.

KEY TERMS

Gluconeogenesis
Production of glucose from keto acid carbon skeletons from deaminated amino acids, from the glycerol portion of triglycerides, or from certain carbohydrate metabolites.

Glycogenolysis
Specific term for the conversion of glycogen into glucose in the liver.

Deamination
Removal of an amino group (NH_2) from an amino acid.

Keto Acid
Amino acid residue after deamination; the glycogenic keto acids can be converted to glucose.

TO SUM UP

Digestion breaks down the food we eat to release and convert nutrients to simple forms that the body can use. Digestion involves two types of activities: mechanical and chemical. Muscle action breaks down food through mixing and churning motions and moves the food mass along the gastrointestinal tract. The chemical activity of gastrointestinal secretions breaks food molecules into smaller and more simple components for absorption. Monosaccharides (simple sugars) and amino acids are water soluble and pass from the mucosal cells of the small intestine into the portal blood. Long-chain fatty acids must be packaged in lipid-protein complexes that enter the lymph and then pass through the thoracic duct into the general circulation. The enormous population of bacteria found in the colon participates in immune function and the synthesis and absorption of important nutrients. The day-to-day function of the gastrointestinal tract, often taken for granted, represents a highly coordinated and efficient body system. The breakdown products released through digestion—glucose, amino acids, and fatty acids—participate in multiple metabolic pathways under hormonal and enzymatic control, producing energy, control agents, and tissues necessary for life and health.

QUESTIONS FOR REVIEW

1. You have just eaten a lunch that included a hamburger on a whole wheat bun, a glass of low-fat milk, and a bunch of grapes. Trace the digestion and final use of each of the macronutrients present in your lunch. What are (a) the enzymes, locations, and breakdown products formed in the complete digestion of these foods; (b) the routes taken by the breakdown products after absorption; and (c) one possible body use?
2. It is said that "food does not really enter the body until it is absorbed." What does this mean? What mechanisms support the absorption of nutrients against a concentration gradient?
3. How might long-term antibiotic use affect the overall function of the gastrointestinal tract? What might be the consequences for nutritional status and health?
4. Discuss the roles of muscle movements and motions in digestion. What are the physiologic or pathologic consequences when (a) movement is absent or too slow and (b) when movement is too rapid?
5. You are working with an older adult who suffered a stroke, resulting in damage to the nerves in his head and throat. What are the implications for his food intake and nutritional well-being?
6. You are working with a young woman who has indicated that she is lactose intolerant and has deleted all dairy products from her diet: (a) What do you need to know about her symptoms and when they occurred? (b) Develop a daily protocol for gradually adding lactose-containing foods to her diet. (c) Prepare a list of calcium-containing foods that will meet her Dietary Reference Intake (DRI) for calcium if consumption of dairy products is not an option.
7. Visit a local supermarket or drug store and examine three over-the-counter medications that claim to (a) reduce stomach acid or (b) alleviate abdominal discomfort or intestinal gas. Make a table

that includes each product and list the active ingredients on the product label. Visit the National Library of Medicine/National Institutes of Health MedlinePlus website at http://www.nlm.nih.gov/medlineplus/druginformation.html or consult another drug index to identify the specific actions of each ingredient. What is the mechanism by which each active ingredient is believed to bring about the desired effect? What is the relative safety of this drug based on the possible side effects or contraindications?

8. Describe the complementary roles of insulin and glucagon in regulating blood glucose levels. What are the effects of these hormones over the course of a day for an individual who eats breakfast at 7:00 a.m., lunch at 12:00 p.m., and dinner at 6:00 p.m., with no snacks?

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FURTHER READINGS AND RESOURCES

Readings

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Marx W, Kiss N, McCarthy AL, et al: Chemotherapy-induced nausea and vomiting: A narrative review to inform dietetics practice, *J Acad Nutr Diet* 116(5):819, 2016.

[These authors provide insight to dietary approaches for treating digestive disorders encountered in the clinical setting.]

Websites of Interest

- National Institutes of Health, National Center for Alternative and Complementary Medicine. This site offers information on herbs sometimes recommended for digestive disorders such as chamomile, ginger, peppermint oil, and turmeric, noting usefulness and risk, if any. https://medlineplus.gov/druginfo/herb_All.html.
- National Institutes of Health, National Center for Complementary and Integrative Health; Probiotics: In Depth. This site discusses the effectiveness, safety, and side effects of probiotics. https://nccih.nih.gov/health/probiotics/introduction.htm.
- National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; Lactose Intolerance. This site describes causes, diagnosis, and useful interventions for lactose maldigesters. http://digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/index.aspx.