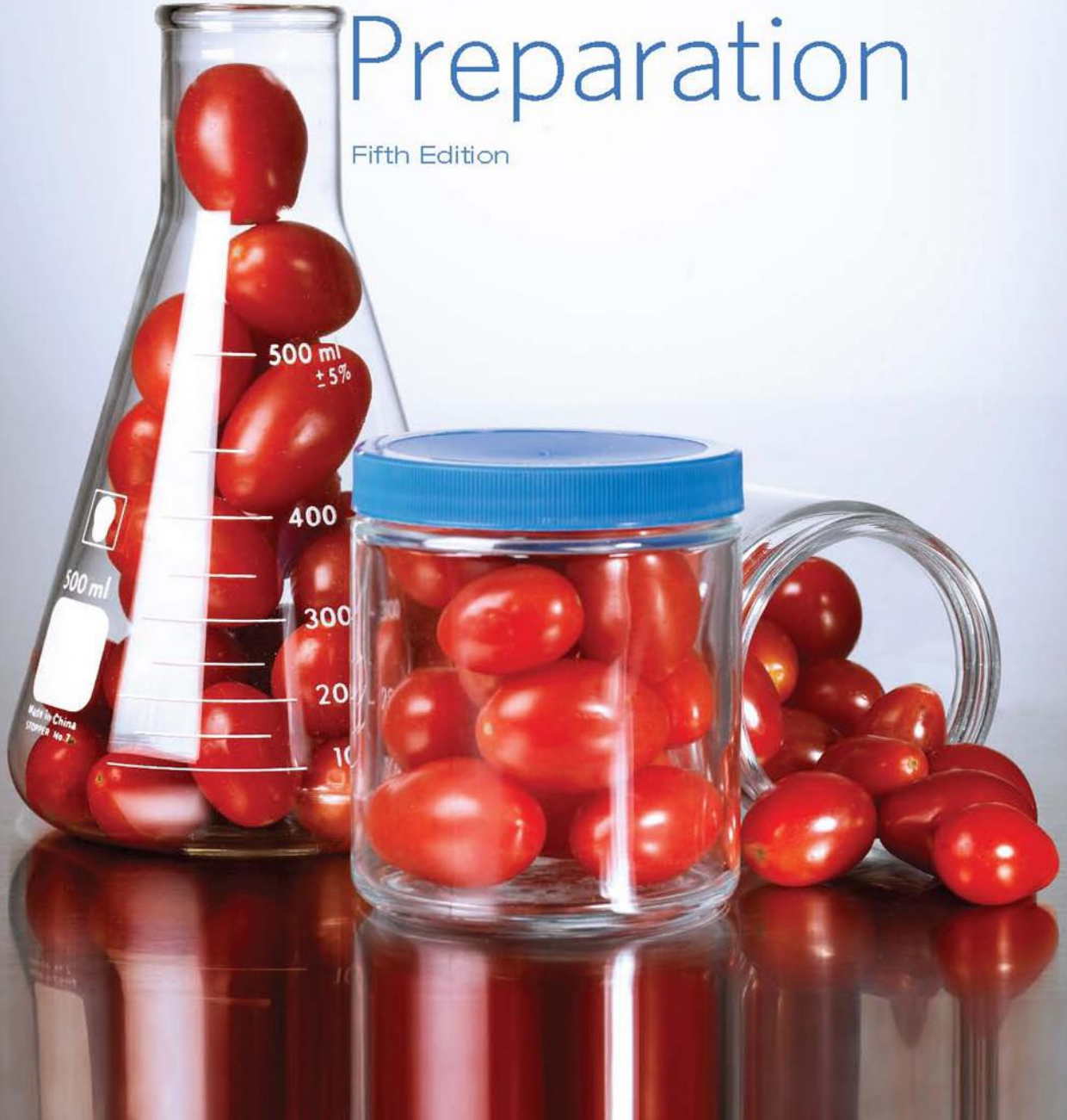
AMY BROWN

Understanding Food Principles and Preparation

Fifth Edition



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AMY BROWN
University of Hawaii at Manoa

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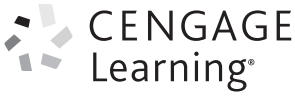

***Understanding Food: Principles and Preparation*, Fifth Edition**
Amy Brown

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Cover Image: ©Frank Bean/GettyImages

WCN: 02-200-208

Library of Congress Control Number: 2013942536

ISBN-13: 978-1-133-60715-1

ISBN-10: 1-133-60715-2

Cengage Learning
200 First Stamford Place, 4th Floor
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Printed in the United States of America
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Brief Contents

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Preface

***Comprehensive* is the word that describes *Understanding Food, the* best-selling textbook in its field. It brings together the most current information in food science, nutrition, and food service. Founded on research from more than thirty-five journals covering these disciplines, the text incorporates the very latest information on food—its science and its application. *Understanding Food: Principles and Preparation*, 5th edition, provides students with a broad foundation to launch a career in any of these food-related fields.**

ORGANIZATION OF CONTENT

Understanding Food is organized according to the various food disciplines. Part I represents information related to food science and nutrition, such as food selection, sensory and physical evaluation, and food chemistry. Part II covers aspects of food service from food safety to food preparation basics to meal management. Part III covers all of the standard food items arranged into proteins (meat, poultry, fish, dairy, and eggs); phytochemicals (vegetables, fruits, soups, salads, and gelatins); complex carbohydrates (cereals, flour, and breads); refined carbohydrates and fat (sweeteners, fats and oils, cakes and cookies, pies and pastries, candy, and frozen desserts); and water (beverages) groupings. Part IV relates to the food industry in terms of food preservation, government food regulations, and food careers. The last chapter, on food careers, is an invaluable advisement session introducing students to the many careers in food and nutrition. In addition, the Professional Profile feature found in many chapters spotlights individuals working in various areas of the food industry, so students really get a hands-on understanding of various career opportunities. Extensive appendixes provide additional key information, including approximate food measurements, weights and measures, storage temperatures, ingredient substitutions, flavorings and seasonings, and more.

FEATURES

The unique features of this text allow flexibility in teaching and create a dynamic learning environment for students.

- **Career Corner** features provide interviews with people working in the food and nutrition arena to help students on their career path.
- **How and Why** inserts answer the questions most frequently asked by students, sparking natural curiosity and exercising the mind's ability to answer.
- **Chemist's Corner** features provide more advanced information on food chemistry for students and instructors who wish to further explore this topic, allowing flexibility in the level of food chemistry presented within the individual course.
- **Calorie Control** teaches students how to identify food sources of kcalories, how many daily kcalories are recommended, and how to practice portion control.
- **Nutrient Content** boxes provide an overview of the nutritional composition of the foods.
- **Pictorial Summarie**s are a proven favorite with readers. These pictorial chapter summaries use a combination of art and narrative text to encapsulate the key concepts in each chapter for student review.
- **Key terms,** boldfaced in the text, are defined on the same page to allow for quick review of the essential vocabulary in each chapter. A glossary at the end of the book assembles all of the key terms in one place.
- **Functions of ingredients** are highlighted in the introduction to each chapter to aid students in successful food product development and food preparation. They introduce a focus of the food industry that is often missing in other books.
- **Food additive information** has been incorporated throughout the book.
- **Problems and causes tables** summarize the problems that may occur when preparing specific food products and describe the possible causes, providing students with a handy reference tool for deciphering "what went wrong."
- **A 16-page full-color insert** displays exotic varieties of fruits and vegetables, salad greens, flowers used in salads, traditional cuts of meats (including the lowest-fat meat cuts), and much more, all with detailed captions describing use and preparation tips.
- **Chapter review questions** help students prepare for both their class exams and the Academy of Nutrition and Dietetics registration examination.

The dynamic world of food changes rapidly as new research constantly adds to its ever-expanding knowledge base. *Understanding Food: Principles and Preparation,* 5th edition, is designed to meet the needs of this evolving and expanding discipline and to provide students with a strong foundation in any food-related discipline that they select.

NEW TO THIS EDITION

Each chapter of *Understanding Food* has been revised to reflect the evolution of research, consumer preferences, and food-service practices since the publication of the prior edition. Specific additions and other enhancements for the fifth edition are detailed here.

- **Chapter 1:** Updated information on the *Dietary Guidelines for Americans,* including MyPlate, and added a figure comparing the typical U.S. diet to the *Dietary Guidelines;* updated statistics on diversity in the

U.S. population; added information on classifications of natural and processed foods.

- **Chapter 2:** Added a description of electronic noses.
- **Chapter 3:** Enhanced the discussion of water's structure and properties, adding a "Chemist's Corner" feature on calculating the effects of solute concentration on water's boiling and freezing points; reorganized and expanded the discussion of dispersions, adding a figure showing forms of dispersion destabilization, a more in-depth explanation of formation of saturated and supersaturated solutions, and a table describing various types of dispersions; added information on fructooligosaccharides; updated the discussion of food fiber measurement; enhanced the explanation of the Maillard reaction.
- **Chapter 4:** Modified the "food risk road" and thermometers figures to improve clarity; added information on the FDA Food Safety Modernization Act, *Clostridium perfringens,* and *Toxoplasma gondii;* updated statistics on foodborne illness incidence; added a "Chemist's Corner" feature on measurement of protein in foods; expanded the discussion of food safety surveillance.
- **Chapter 5:** Clarified the discussion of induction; updated the information on dietary sodium intakes and reduction; added "How & Why?" features on preparation of substitute cake flour and the differences among hot peppers and powders made from them.
- **Chapter 6:** Added figures of a healthy meal plan and cycle menu; thoroughly updated the discussion of USDA meal plans; added information on the impact of the Healthy, Hunger-Free Kids Act of 2010 and the Patient Protection and Affordable Care Act of 2010.
- **Chapter 7:** Clarified the discussion of protein contraction/relaxation; updated the information on antibiotic use in livestock; clarified the explanation of meat quality problems and their causes; expanded the explanation of the process of rigor mortis; added information on lean finely textured beef (a.k.a. "pink slime"); updated and expanded the section on meat packaging for storage.
- **Chapter 8:** Improved the figure showing how to truss poultry.
- **Chapter 9:** Enhanced the figures showing shrimp deveining and "count per pound" sizes; added information on DNA bar coding of fish.
- **Chapter 10:** Expanded the discussion of casein and whey proteins; updated the "How & Why?" feature contrasting milk intolerance and allergy; clarified the discussion and table on pasteurization techniques; thoroughly updated the discussion of probiotics and prebiotics.
- **Chapter 11:** Enhanced the explanation of enzymes used in cheese coagulation, including bacteria-produced and plant-derived enzymes.
- **Chapter 12:** Updated the information on nutrient contents of eggs.
- **Chapter 13:** Updated the vegetable intake recommendations; clarified the explanation of soy sauce; expanded the "How & Why?" feature on the distinctions among potatoes, sweet potatoes, and yams.
- **Chapter 14:** Updated and reorganized the nutrient content information; updated the discussion of "superfruits" and phytochemicals in fruits.
- **Chapter 15:** Clarified the discussion of bouillons, adding a "How & Why?" feature explaining the distinctions between broths and stocks; expanded discussions of gel preparation and dishes prepared with whipped gels.
- **Chapter 16:** Updated the data and figure on world grain production; added information on black and red rice varieties; reorganized the section of types of grains to categorize them by gluten content, and the grain preparation section to improve flow and clarity.
- **Chapter 17:** Clarified the figures classifying flour proteins and demonstrating the proposed function of lipids in gluten development; reorganized the section on types of flour to categorize them by gluten content.
- **Chapter 18:** Better illustrated starch gelatinization, gel formation, retrogradation, and dextrinization using the example of a pie filling; added a figure categorizing the methods of modifying starches and a table of resistant starch types.
- **Chapter 19:** Updated the references.
- **Chapter 20:** Clarified the proofing discussion; reorganized the figures to follow the bread preparation process sequentially.
- **Chapter 21:** Clarified the use of terminology (e.g., "sucrose" is used consistently to refer to that sugar, and the two meanings of "fruit sugar" are clearly differentiated); enhanced the discussions of high-fructose corn syrup and invert sugar production; added details about luo han guo and stevia extracts to the nonnutritive sweeteners section and table; added a "How & Why?" feature explaining the different ways to express solubility measurements.
- **Chapter 22:** Added a "How & Why?" feature explaining how emulsifiers are distinct from other surfactants; added a "Chemist's Corner" feature on the factors affecting fatty acid melting points; added "How & Why?" features on derivation of the terms *margarine* and *shortening*.
- **Chapter 23:** Added a figure showing several traditional types of unshortened cakes.
- **Chapter 24:** Clarified the distinctions between laminated and nonlaminated pastries and among long flake, short flake, and mealy pastry textures; added photos of types of pies to Table 24-1 and a figure featuring photos of different types of nonlaminated and laminated pastries.
- **Chapter 25:** Added a figure comparing saturation and supersaturation of solutions, a "Chemist's Corner" feature on factors promoting small crystal formation in candies, and a "How & Why?" feature explaining how interfering agents work.
- **Chapter 26:** Clarified various minor points and updated the statistics.
- **Chapter 27:** Streamlined the content and organization to focus on the important characteristics of each type of beverage and its preparation.

- **Chapter 28:** Added figures showing edible biosensors, freeze-drying, irradiation equipment, and irradiation effects on bacteria; expanded the discussion of fermentation; added a "How & Why?" feature on nano foods; added a discussion of sous-vide as a heat preservation method.
- **Chapter 29:** Added information on the FDA Food Safety Modernization Act; clarified the discussion of health claims, updating the list of approved qualified health claims.
- **Chapter 30:** Added a table of salaries for nutrition- and food-related jobs; updated the information on relevant professional organizations, websites, and publications. Added the new registered dietitian nutritionist (RDN) option for registered dietitians (RDs).

ANCILLARY MATERIALS

An assortment of student and instructor support materials, thoroughly updated for the fifth edition, are available:

- The print **Lab Manual,** revised by Janelle M. Walter (Baylor University), presents food experiments and recipes to demonstrate the principles discussed in the text. Pretest questions and materials/time needed information for instructors enhance the lab units, which parallel the organization and content of the text.
- **Cengage Learning Testing powered by Cognero.** A flexible, online system that allows you to author, edit, and manage test bank content from multiple Cengage Learning solutions. Create multiple test versions in an instant. Deliver tests from your LMS, your classroom, or wherever you want. Test questions for this edition were written by Joan Aronson (New York University).
- An **Instructor's Manual** written by Joan Aronson and Cheryl Houston (Fontbonne University), available electronically, features engaging classroom activities, objectives, recommendations, and lecture outlines.
- **Instructor Companion Website.** Everything you need for your course in one place! This collection of book-specific lecture and class tools is available online "http://www.cengage.com/login" www.cengage.com/login. Access and download PowerPoint presentations, images, instructor's manual, videos, and more.
- The text's **CourseMate Website** offers various test preparation exercises for students, including quizzes, and instructor downloads.

ACKNOWLEDGMENTS

Many individuals assisted me in the development of this textbook. First and foremost I thank Peter Marshall, Publisher, without whose knowledge and experience this book would never have come to be. I also thank Peggy Williams, who masterfully brought this book to the completion of yet another edition.

I also extend my thanks to the outstanding members of the Cengage nutrition team: Elesha Feldman, Developmental Editor, for helping me revise and enhance the fourth and fifth editions with incredible finesse, eagle editor eye, and an over and above the call of duty work ethic; Elizabeth Howe, second edition Developmental Editor, for her excellent skills in working with me to create a well-organized manuscript; and Tom Ziolkowski, Marketing Manager, who understands the process of book publishing and marketing to such a high degree that his presence alone is invaluable. My thanks to Yolanda Cossio, Publisher; Kellie Petruzzelli, Editorial Assistant; and Bob Kauser and Roberta Broyer, Permissions Editors. I also thank Michelle Clark at Cengage and the tremendous production staff at MPS Limited who worked miracles on this book, especially Carolyn Deacy, Lynn Lustberg, and Naman Mahisauria.

A special thanks goes to the person who kindled my writing career, Nackey Loeb, Publisher of *The Union Leader.* Your early support and encouragement did far more than you will ever know.

Many colleagues have contributed to the development of this text. Their thoughtful comments provided me with valuable guidance at all stages of the writing process. I offer them my heartfelt thanks for generously sharing their time and expertise. They are:

Renee Hirschman Alster, MS, RD
Brooklyn College CUNY

Elizabeth Christian
Texas Woman's University

Kristi Crowe, PhD, RD, LD
University of Alabama

Alyce D. Fly, PhD
Indiana University

Keely Hawkins, MS
Texas Tech University

Georgia Jones, PhD
University of Nebraska–Lincoln

Lalitha Samuel, PhD
Lehman College CUNY

Finally, I wish to express my appreciation to the students. Were it not for them, I would not have taken pen to paper. I am grateful to be part of your academic journey.

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About the Author

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Amy Christine Brown received her PhD from Virginia Polytechnic Institute and State University in 1986 in the field of Human Nutrition and Foods. She has been a college professor and a registered dietitian with the Academy of Nutrition and Dietetics since 1986. Dr. Brown currently teaches at the University of Hawaii's John A. Burns School of Medicine in the Department of Complementary and Alternative Medicine. Her research interests are in the area of bioactive plant substances beneficial to health and medical nutrition therapy. Some of the studies she has conducted include "Diet and Crohn's disease," "Potentially harmful herbal supplements," "Kava beverage consumption and the effect on liver function tests," and "The effectiveness of kukui nut oil in treating psoriasis." Selected research journal publications include: "Position of the American Dietetic Association: functional foods" (*Journal of the American Dietetic Association*); "The Hawaii Diet: Ad libitum high carbohydrate, low fat multi-cultural diet for the reduction of chronic disease risk factors" (*Hawaii Medical Journal*); "Lupus erythematosus and nutrition: A review" (*Journal of Renal Nutrition*); "Dietary survey of Hopi elementary school students" (*Journal of the American Dietetic Association*); "Serum cholesterol levels of nondiabetic and streptozotocin-diabetic rats" (*Artery*); "Infant feeding practices of migrant farm laborers in northern Colorado" (*Journal of the American Dietetic Association*); "Body mass index and perceived weight status in young adults" (*Journal of Community Health*); "Dietary intake and body composition of Mike Pigg—1988 Triathlete of the Year" (*Clinical Sports Medicine*); and numerous newspaper nutrition columns.

Feedback welcome, contact: amybrown@hawaii.edu

To Jeffery Blanton

The person who saw me through four years of writing the first edition. Four years, four thousand laughs, and only one you.

Always Grateful,

Amy Christine Brown

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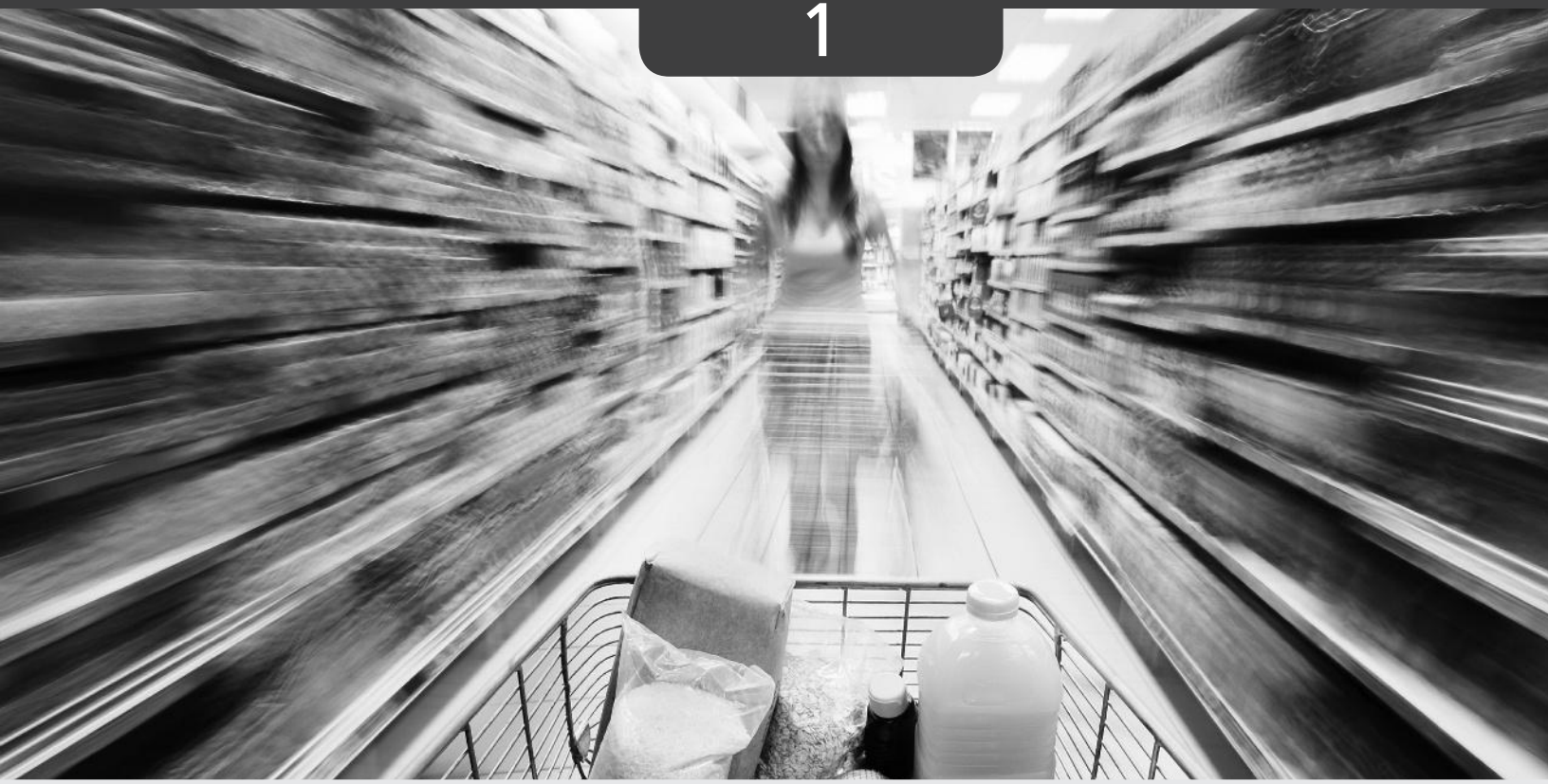


Don Bayley/RapidEye/istockphoto.com

Food Selection

Not too long ago, meats, milk, grains, nuts, vegetables, and fruits were the only foods available for consumption. Today, food companies offer thousands of prepared and packaged foods, which are primarily mixtures of these basic ingredients but often include natural and/or artificial additives. This wide assortment of processed foods makes planning a nutritious diet more difficult, rather than easier. Food companies compete fiercely to develop ever newer and more attractive products. The food scientists they employ focus on why people eat, what they eat, and which food characteristics entice consumers to choose one brand over another.

People choose foods and beverages for at least five basic reasons: how foods look and taste, health, cultural and religious values, psychological and social needs, and budgetary concerns (17). This chapter addresses the factors influencing consumer food selection.

SENSORY CRITERIA

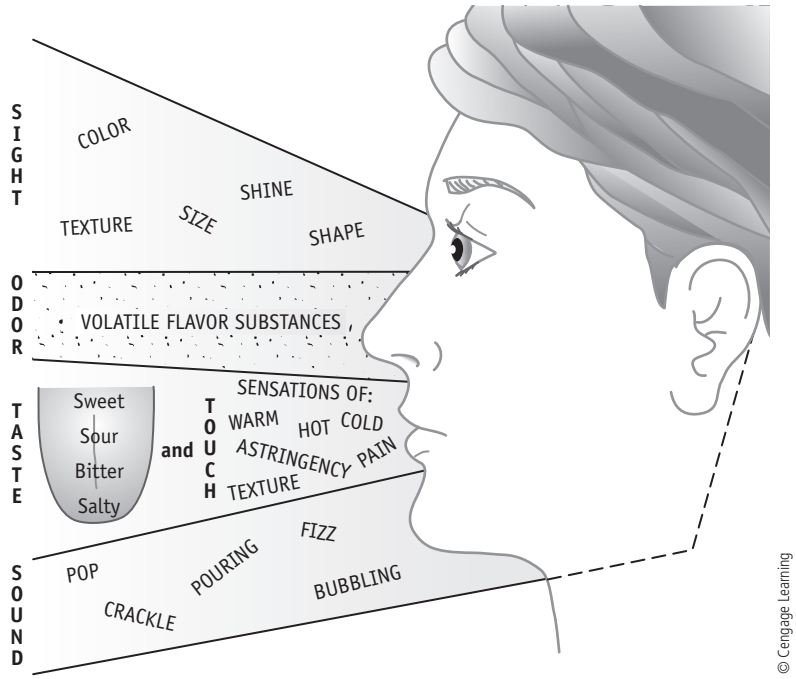
When people choose a particular food, they evaluate it consciously or unconsciously, primarily by how it looks, smells, tastes, feels, and even sounds (Figure 1-1). These sensory criteria are discussed first because of their strong influence on food selection. How a food or beverage affects the senses is more important to most consumers than other criteria for food selection. The sensory criteria of sight, odor, and taste are evaluated below.

Sight

The eyes receive the first impression of foods: the shapes, colors, consistency, serving size, and presence of any outward defects. Color can denote the ripeness, strength of dilution, and even degree to which the food was heated. Black bananas, barely yellow lemonade, and scorched macaroni send visual signals that may alter a person's choices. Color can be deceiving; if the colors of two identical fruit-flavored beverages are different, people often perceive them as tasting different even though they are exactly the same (88). People may judge milk's fat content by its color. For instance, if the color of reduced-fat (2%) milk is improved, it is often judged to be higher in fat content, smoother in texture, and better in flavor than the reduced-fat milk with its original color (71).

The color palette of foods on a plate also contributes to or detracts from

FIGURE 1-1 Sensory impressions of food provided by the five senses.



their appeal. Imagine a plate containing baked flounder, mashed potatoes, boiled cabbage, and vanilla ice cream, and then compare it to one that contains a nicely browned chicken breast, orange sweet potatoes, green peas, and blueberry cobbler. Based on eye appeal alone, most people would prefer the latter.

Odor

Smell is almost as important as appearance when people evaluate a food item for quality and desirability. Although the sense of smell is not as acute in human beings as it is in many other mammals, most people can differentiate between 2,000 and 4,000 odors, whereas some highly trained individuals can distinguish as many as 10,000 (5).

Classification of Odors

Naming each of these thousands of odors separately would tax even the most fertile imagination; researchers have categorized them into major groups. One classification system recognizes six groups of odors: spicy, flowery, fruity, resinous (eucalyptus), burnt, and foul. The other widely used grouping scheme consists of four categories: fragrant (sweet), acid (sour), burnt, and caprylic (goaty) (5). A newer proposed classification divides odors into categories based on whether they are perceived as edible (e.g., fruit, candy, bakery, or spice) or inedible (e.g., clean, flower, and cosmetic) and overlaps with previous classification systems (98).

Detecting Odors

Regardless of the classifications, most odors are detected at very low concentrations. Vanillin can be smelled at 2×10^{-10} (0.0000000002) mg per liter of air (18). The ability to distinguish between various odors diminishes over the time of exposure to the smells; this perception of a continuously present smell gradually decreasing over time is called *adaptation*. People living near a noxious-smelling paint factory will, over time, come not to notice it, whereas visitors to the area may be taken aback by the odor.

We are able to detect odors when **volatile molecules** travel through the air and some of them reach the yellowish-colored **olfactory** epithelium, an area the size of a quarter located inside the upper part of the nasal cavity. This region is supplied with olfactory cells that number from 10 million to 20 million in a human and about 100 million in a rabbit (13), reflecting the difference in importance of the sense of smell between people and rabbits. The exact function of these specialized cells in the sense of smell is not well understood.

Interestingly, molecules can sometimes reach the olfactory epithelium by first going through the mouth and then back up to the nose. Who has not experienced the feeling of bubbles tingling in the nose brought on by drinking a carbonated beverage while simultaneously being made to laugh unexpectedly?

Volatile molecules Molecules capable of evaporating like a gas into the air.

Olfactory Relating to the sense of smell.

How & Why?

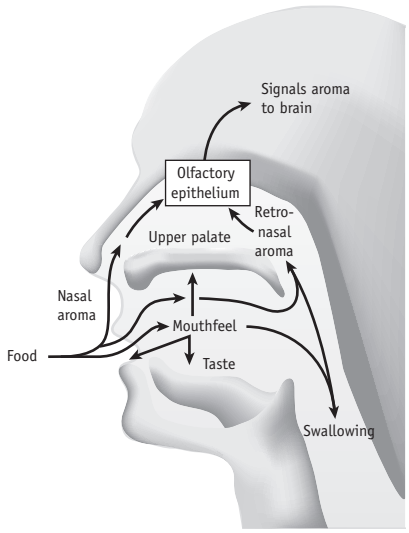
Imagine the scent of chocolate chip cookies wafting through the house as they bake. How does this smell get carried to people? Why is the odor of something baking more intense than the odor of cold items like ice cream or frozen peaches?

Heat converts many substances into their volatile form. Because only volatile molecules in the form of gas carry odor, it is easier to smell hot foods than cold ones. Hot coffee is much easier to detect than cold coffee. Relatively large molecules such as proteins, starches, fats, and sugars are too heavy to be airborne, so their odors are not easily noticed. Lighter molecules capable of becoming volatile are physically detected by the olfactory epithelium by one of two pathways: (1) directly through the nose and/or (2) during eating when they enter the mouth and flow retronasally, or toward the back of the throat and up into the nasal cavity (Figure 1–2) (70).

Taste

Taste is usually the most influential factor in people's selection of foods (20). Taste buds—so named because the arrangement of their cells is similar to the shape of a flower bud—are located primarily on the tongue, but are also found on the mouth palates and in the pharynx. These taste detectors are not

FIGURE 1-2 Detecting aroma, mouthfeel, and taste.



found on the flat, central surface of the tongue, but rather on the tongue's underside, sides, and tip.

Mechanism of Taste

What is actually being tasted? Many tasted substances are a combination of nonvolatile and volatile compounds. In order for a substance to be tasted, it must be dissolved in liquid or saliva, which is 99.5% water. In the middle of each taste bud is a pore, similar to a little pool, where saliva collects.

When food comes into the mouth, bits of it are dissolved in the saliva pools and they come into contact with the cilia, small hair-like projections from the **gustatory** cells. The gustatory cells relay a message to the brain via one of the cranial nerves (facial, vagus, and glossopharyngeal). The brain, in turn, translates the nervous electrical impulses into a sensation that people recognize as "taste." As people age, the original 9,000 to 10,000 taste buds begin to diminish in number, so people over 45 often find themselves using more salt, spices, and sugar in their food. Genetics also plays an important role in taste; for example, some people can detect monosodium glutamate (MSG) in foods because it contains glutamate. Another important factor influencing the ability of a person to taste is the degree to which a compound can dissolve (59). The more moisture or liquid, the more the molecules triggering flavor can dissolve and spread over the tongue to contact the taste buds (34).

The Five Taste Stimuli

The common concept of a "tongue map," in which different areas on the tongue are associated with the basic types of tastes—sweet, sour, bitter, and salty—has been largely discredited (14). Nonetheless, these four basic tastes, along with a fifth known as savory (*umami*, a Japanese word meaning "delicious"), are perceived in response to certain chemical stimuli. The time it takes to detect taste stimuli varies from a split second for salt to a full second for bitter substances (13). Bitter tastes, therefore, have a tendency to linger. The chemical basis of these five categories of taste is as follows:

- The sweetness of sugar comes from the chemical configuration of its molecule. A long list of substances yield the sweet taste, including sugars, glycols, alcohols, and aldehydes. Little is known, however, about the sweet taste receptor and how "sweetness" actually occurs (34).
- Sour taste comes from the acids found in food. It is related to the concentration of hydrogen ions (H^+), which are found in the natural acids of fruits, vinegar, and certain vegetables. The perceived unpleasantness of too much sour food may protect against disrupting the body's acid–base balance (14).
- Bitterness is imparted by compounds such as caffeine (tea, coffee), theobromine (chocolate), and phenolic compounds (grapefruit). Many other substances yield bitter tastes, including the alkaloids often found in poisonous plants (7). Thus, the ability to taste bitterness can warn us against ingesting some toxins.
- Salty taste comes from ionized salts—for example, from the sodium ions (Na^+) in sodium chloride (NaCl) or other salts found naturally in some foods.
- Savory (*umami*) taste was first identified in 1908 by researchers at Tokyo Imperial University. *Umami* is attributed to glutamate, an amino acid that imparts the taste of beef broth, but without the salt (62).

Taste Interactions

Each item used in food preparation contains several compounds, and bringing these items together creates new tastes when all their compounds interact.

Gustatory Relating to the sense of taste.

Factors Affecting Taste

Not everyone perceives the taste of apple pie the same way. There is considerable genetic variation among individuals in sensitivity to basic tastes (70). Tasting abilities may also vary within the individual, depending on a number of outside influences (67). One such factor affecting taste is the temperature of a food or beverage. Taste buds operate best at temperatures of around 86°F(30°C). As the temperature of foods or beverages goes below 68°F(20°C) or above 86°F(30°C), it becomes harder to distinguish their tastes accurately. For example, very hot coffee tastes less bitter, whereas slightly melted ice cream tastes sweeter. Other factors influencing taste include the color of the food; the time of day it is eaten; and the age, sex, and degree of hunger of the taster (35). Psychological factors, such as preconceived ideas based on appearance or on previous experiences with a similar food, also affect a person's perception of taste. For instance, cherry-flavored foods are expected to be red, but if they are colored yellow, they become difficult to identify as cherry. Also, unpleasant experiences associated with a food may influence the perceived taste of that food in the future.

Variety in available food choices also affects taste. This can be seen when the "taste," or appetite, for a food eaten day after day starts to diminish. Even favorite foods can eventually lose their appeal when consumed daily. Some weight-reducing fad diets that severely restrict choices are based on the idea that people will get tired of eating just one type of food and therefore eat less. A routine of grapefruit for breakfast, grapefruit for lunch, and grapefruit for dinner quickly becomes boring and unappetizing.

How & Why?

Why does a dash of salt make some foods sweeter?

Taste sensitivity depends on a number of factors, including: (1) the amount of time allowed to taste a substance, (2) the concentration of the substance generating the taste, and (3) the individual's ability to detect various tastes. The threshold concentration is the minimum concentration required to detect a substance. This is not easy to determine, because people more sensitive to a particular taste than others can detect it at a lower concentration. Below the threshold concentration are subthreshold concentrations that are not detected but may influence the person's ability to perceive other tastes. For example, subthreshold salt levels increase perceived sweetness while decreasing perceived acidity, even though the actual amount of sugar or acid in the food is unchanged. Conversely, subthreshold sugar or acid concentrations make a food taste less or more salty, respectively. This principle can be applied to foods when too much salt is added to soups or stews. Even though the salt cannot be removed, adding a small amount of sugar will make the dish taste less salty (66). Trace additions of sugar also make acids taste less sour and coffee or tea less bitter. Small amounts of salt sprinkled on grapefruit or added to fruit pies tend to decrease tartness and enhance sweetness. Some compounds, like monosodium glutamate, often used in Chinese cooking, actually improve the taste of meat and other foods by making them sweeter (53, 69).

Definition of Flavor

In examining the factors affecting taste, it is important to distinguish between taste and **flavor.** Taste relies on the taste buds' connection to the brain via nerve cells, which signal the sensations of sour, salt, sweet, bitter, and savory. Flavor is a broader concept than either taste or aroma; in fact, it includes both. The perception of aroma is triggered by volatile compounds reaching the nose and provides about 75% of the impression of flavor (18, 79). Thus, a food without aroma has very little flavor. To get some idea of how the ability to smell affects flavor perception, think of having a cold with a badly stuffed-up nose. Everything tastes different. The nasal congestion interferes with the function of the olfactory sense, impairing the ability to detect the aromas contributing to the perception of flavor. Some people apply this principle to their advantage by pinching their nostrils shut to lessen the bad flavor of a disagreeable medicine they must swallow.

Whether in a package or on a plate, a commercial food's flavor is the single most important factor determining its success in the marketplace (21).

How & Why?

How are food flavors preserved during storage?

Flavors, regardless of the medium in which they are dissolved, do not stay at the same intensity day after day, but diminish over time. Sensory chemists and flavor technologists know that one way to keep the food products sold by manufacturers from losing their appeal is to prevent the volatile compounds responsible for flavor from deteriorating, escaping, or reacting with other substances. In devising flavor preservation strategies, they look at processing, storage, and cooking methods, all of which affect the volatile flavor compounds. One of the major functions of protective packaging is to retain a food's flavor. Packaging guards flavor in several ways. It protects against vaporization of the volatile compounds and against physical damage that could expose food to the air and result in off odors. It keeps unpleasant odors from the outside from attaching to the food. It also prevents "flavor scalping"—the migration of flavor compounds from the packaging (sealers, solvents, etc.) to the food or vice versa (54).

Touch

The sense of touch, whether it operates inside the mouth or through the fingers, conveys to us a food's texture, consistency, astringency, and temperature.

Texture is a combination of perceptions, with the eyes giving the first clue. The second comes at the touch of fingers and eating utensils, and the third is mouthfeel, as detected by the teeth and the tactile nerve cells in the mouth.

Flavor The combined sense of taste, odor, and mouthfeel.

CAREER CORNER

Ben Cohen and Jerry Greenfield—Cofounders of Ben & Jerry's

Steve Liss/Time Life Pictures/Getty Images

Ben Cohen and Jerry Greenfield

It's hard to believe, but some people taste food for a living. "Taste testers" have such sensitive taste buds or olfactory detection that they are hired by food companies to taste new products being developed. Food companies need to be sure that the absolute best product is being produced for consumers. The first taste tester at Ben & Jerry's Ice Cream was the company's cofounder, Ben Cohen. He had such weak taste buds that he kept asking the flavor developers for more sugar, salt, chocolate cookies, or caramel. His challenged taste buds made Ben & Jerry's ice creams famous for their intense flavors.

Ben & Jerry's started small. Ben Cohen and Jerry Greenfield were high school friends, and Ben drove an ice cream truck selling ice cream pops to kids. He went to college, dropped out, and returned to his ice cream job. Ben also taught crafts in a residential school for emotionally disturbed children, where he began experimenting with ice cream–making as a craft activity for the students. This led to him selling ice cream with Jerry, whose application to medical school had been rejected twice. Their first store was "Ben & Jerry's Homemade Ice Cream Parlor" in a renovated gas station in Vermont. The rest is ice cream history (www.benjerry.com).

Textural or structural qualities are especially obvious in foods such as apples, popcorn, liver, crackers, potato chips, tapioca pudding, cereals, and celery, to name just a few. Textures can be described as coarse (grainy, sandy, mealy), crisp, fine, dry, moist, greasy, smooth (creamy, velvety), lumpy, rough, sticky, solid, porous, bubbly, or flat. Tenderness, which is somewhat dependent on texture, is judged by how easily the food gives way to the pressure of the teeth.

Consistency is only slightly different from tenderness; it is expressed in terms of brittleness, chewiness, viscosity, thickness, thinness, and elasticity (rubbery, gummy).

Astringency, which causes puckering of the mouth, is possibly due to the drawing out of proteins naturally found in the mouth's saliva and mucous membranes (13). Foods such as cranberries, lemon juice, and vinegar have astringent qualities.

Another term used in the sensory perception of foods is **chemesthesis.** Chemesthesis defines how certain foods that are not physically hot or cold appear to give the impression of being "hot" (hot salsa) or "cooling" (cucumbers) when placed on the tongue (37). Although extremely hot temperatures can literally burn the taste buds (they later regenerate), the other kind of "heat" experienced with food results from eating "hot" peppers (Chemist's Corner 1-1). Capsaicin (cap-SAY-iss-in) is the chemical responsible for the "heat" that many people enjoy in moderation, as well as the real pain experienced when an excess irritates nerves in the nose and mouth. In fact, this compound is so caustic when concentrated that it is used by many law enforcement agencies in place of mace-like sprays.

How & Why?

Why do flavors differ in how quickly they are detected or how long they last?

The amount of fat in a food or beverage determines how intense the flavor is over time. Flavor compounds dissolved in fat (fat-soluble compounds) take longer to be detected and last longer than flavor compounds dissolved in water (water-soluble compounds), which are quickly detected but also disappear much more quickly (18). This explains why a reduced-fat product is unlikely to duplicate the flavor of the original food: the original fat's flavor compounds are missing, causing an imbalance of the other flavors present. Reduced-fat cookies, for example, taste sweeter unless they are modified to compensate for this difference (50). It is even more difficult to replace certain fats that have their own distinctive flavor, such as butter, olive oil, and bacon fat (54).

CHEMIST'S CORNER 1-1

Hot Peppers and Body Chemistry

The warming sensation experienced by some people eating hot peppers (or foods made with them) is due to the body's secreting catecholamines, a group of amines composed of epinephrine (adrenaline), norepinephrine (noradrenaline), and dopamine. These catecholamines activate the "fight-or-flight" response, which normally triggers an increased respiration rate, a faster heart beat, slowed digestion, widened pupils, and enhanced energy metabolism (39, 72).

Consistency A food's firmness or thickness.

Astringency A sensory phenomenon characterized by a dry, puckery feeling in the mouth.

Chemesthesis The ability to feel a food's chemical properties (e.g., cool mints or hot chili peppers).

Hearing

The sounds associated with foods can play a role in evaluating their quality. How often have you seen someone tapping a melon to determine whether it is ripe? Sounds like sizzling, crunching, popping, bubbling, swirling, pouring, squeaking, dripping, exploding (think of an egg yolk in a microwave), and crackling can communicate a great deal about a food while it is being prepared, poured, or chewed. Most of these sounds are affected by water content, and their characteristics thus give clues to a food's freshness and/or doneness.

NUTRITIONAL CRITERIA

Over the past several decades, emerging scientific evidence about health and nutrition has resulted in changing food consumption patterns in the United States (8). Past surveys reveal that at least half of all consumers were reportedly making a major change in their diets, with nutrition being second only to taste in importance to shoppers (96). Currently, about 71 percent of Americans say they are trying to limit the intake of some type of fats, and 66 percent of Americans say they are trying to limit their consumption of saturated fats and/or trans fatty acids. More than half of Americans are trying to limit their consumption of sugars (47). Attempts to improve food habits are related to the increased awareness that a poor diet can be related to some of the leading causes of death—heart disease, cancer, and diabetes—as well as to other common health conditions such as osteoporosis, diverticulosis, and obesity (38).

Calorie The amount of energy required to raise 1 gram of water 1°C (measured between 14.5°C and 15.5°C at normal atmospheric pressure). A *kilocalorie* (kcalorie, kcal), the unit commonly used to measure food energy, is equal to 1,000 calories.

Weight Management

Obesity has reached epidemic proportions in the United States (19). As a risk factor for heart disease, cancer, diabetes, and other health conditions, obesity is one of the biggest and costliest health problems in the nation. Health care costs are higher for people who are obese as compared to people of normal weight (55). Also, billions are spent annually by millions of North Americans seeking "quick fix" weight loss solutions, most of which achieve no permanent results. According to an International Food Information Council survey, most Americans (69%) are trying to reduce or maintain their weight (47). They consider this a strong factor influencing their decision to make dietary changes and remain physically active.

Generally, individuals must restrict their intake of food energy and increase their expenditure of energy (e.g., through bodily movement) in order to lose weight. Energy can be correlated to heat and is measured in units called **calories** (or joules or Btu; see Chemist's Corner 1-2). Food energy is measured in kilocalories (abbreviated kcalories or kcal). The "Measuring Heat Energy" section in Chapter 3 provides further details.

CHEMIST'S CORNER 1-2

Other Units of Measurement for Energy

The metric equivalent of the calorie is the joule (J) or kilojoule (kJ). One joule is defined as the work or energy required to move 1 kilogram of mass 1 meter. One calorie is equivalent to 4.184 joules, whereas 1 kilocalorie equals 4.2 kilojoules. Another measure of heat is the British thermal unit (Btu), which is the amount of energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit. The Btu is more commonly used to measure the heating capacity of fuels used in various industries (heating, power, steam, and air conditioning).

Because a calorie is a unit of measure, not a component of foods (or of the body), it is more accurate to speak of energy rather than calories, unless a specific amount is being discussed. The "Calorie Control" features found in many chapters of this book explain the basics of weight management and provide practical guidelines for making lower-kcalorie food choices to reduce energy intake.

Dietary Guidelines for Americans

In an effort to reduce dietary risk factors for some of the major health conditions affecting Americans, the U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (DHHS) have published the *Dietary Guidelines for Americans* every 5 years since 1980 (93, 94). The 2010 *Dietary Guidelines* for healthy adults published in January 2011 represent the federal government's evidence-based nutritional guidance to promote health, reduce the risk of chronic diseases, and reduce the prevalence of overweight and obesity through improved nutrition and physical activity (83). They also serve to guide federal food programs and nutrition education programs (85). They encourage people to follow the recommendations available at www.choosemyplate.gov (select Dietary Guidelines). In general, a healthy diet emphasizes:

- Staying within daily energy needs for recommended body weights.
- Consuming a variety of vegetables, fruits, whole grains, and fat-free and low-fat milk products.
- Eating lean meats, poultry, seafood, legumes, eggs, seeds, and nuts.
- Keeping intakes of saturated and trans fats, cholesterol, salt (sodium), and added sugars low.

ChooseMyPlate

MyPlate is a pictorial illustration of the concepts of the 2010 *Dietary Guidelines*. It shows people what to put on their plate by dividing it into four sections—vegetables, fruits, grains,

CALORIE CONTROL
Calorie Balance

One out of every three people in the United States was classified as "obese" in 2010 according to the Centers for Disease Control and Prevention (CDC) (10). A website link at the end of this chapter allows each person to calculate his/her body mass index (BMI). This number is a ratio based on a person's weight to height that classifies him or her as underweight, normal weight, overweight, or obese.

The CDC is concerned about obesity because of health consequences, high health care costs, increased absenteeism, and work-related injuries (49). Although many other factors such as environment, genetics, disease, and drugs may contribute to obesity, this book focuses on the primary cause of obesity—too many kcalories (Figure 1-3).

The purpose of the "Calorie Control" sections in this book is to address the obesity epidemic by providing readers with kcalories found in foods and healthful ways to modify their diets. Specific topics to be included are: (1) average daily caloric intakes by Americans (see below), (2) kcalorie sources (see Chapter 3, "Chemistry of Food Composition"), (3) the average number of kcalories found in foods (see individual chapters), (4) suggestions for practicing portion control (see Chapter 5, "Food Preparation Basics" and various individual chapters), and (5) healthful preparation methods (various chapters).

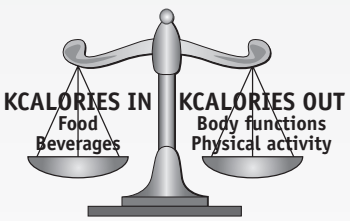
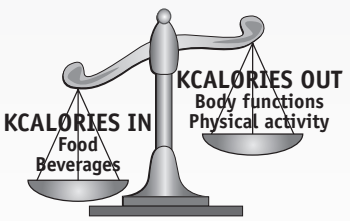
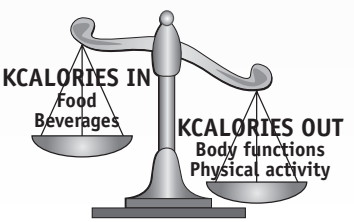
How Many Kilocalories Do People Consume Each DAY?

The Dietary Reference Intakes (DRI) for kcalories (2,403 per day for women and 3,067 for men) exceed those reported by the National Health and Nutrition Examination Survey (2009–2010), which measures the actual kcaloric intakes (1,778 for women and 2,512 for men over 20 years of age) of a population in which one fourth are obese (11). Although it's best for people to determine their specific caloric and nutrient needs by seeing a registered dietitian (RD) or using the USDA's SuperTracker (https://www.choosemyplate.gov/SuperTracker/CreateProfile.aspx), the intakes below serve as general guidelines for healthy adults who wish to "reach" and "maintain" a healthy goal weight:

Women	Approximately 1,600 kcalories for each day
Men	Approximately 2,400–2,600 kcalories for each day

This estimate includes exercising three times a week for at least 20 minutes each session. A person will need more kcalories if they exercise more than three times a week—approximately 300 to 600 kcalories for each hour of aerobic exercise. The exceptions are active (athletes) and larger people, who need more calories; sedate and shorter people, who need fewer calories; and older people, who need fewer kcalories (after 40, people need 100 fewer kcalories for each 10 years of age) (93).

FIGURE 1-3 Caloric balance is like a scale. To remain in balance and maintain your body weight, the kcalories consumed (from foods) must be balanced by the kcalories used (in normal body functions, daily activities, and exercise).

If you are:		Your caloric balance is:
Maintaining Weight		• "IN BALANCE" • You are eating roughly the same number of kcalories that your body is using. • Your weight will remain stable.
Gaining Weight		• "IN KCALORIC EXCESS" • You are eating more kcalories than your body is using. • You will store these extra kcalories as fat and you'll gain weight.
Losing Weight		• "IN KCALORIE DEFICIT" • You are eating fewer kcalories than you are using. • Your body is pulling from its fat storage cells for energy, so your weight is decreasing.

(Continued)

How Many Kilocalories for Each MEAL?

Because it's challenging to count total daily kcalories, the easier method is to break it down for each "meal." For example, a woman requiring 1,600 kcalories (kcal) a day could divide this into three 400-kcalorie meals plus one 400-kcalorie snack (or two 200-kcalorie snacks). The snacks are best eaten midmorning and midafternoon, but can be taken in any combination of kcalories during any part of the day and even as part of a meal. A man requiring 2,400 kcalories a day could divide this into three 600-kcalorie meals plus one 600-kcalorie snack (or two 300-kcalorie snacks).

Starving Is a Bad Idea

About two thirds of a person's kcalories are used to sustain life: heart beating, lungs breathing, body temperature at 97.6°F (36.4°C), and other bodily functions. Most of the remaining 30% of kcalories are burned by activity.

The bottom line is that based on sex, a person should not consume less than the following amount of daily kcalories:

Women	1,200 kcalories (about 70% of 1,600)
Men	1,600 kcalories (about 70% of 2,400)

How to Gain or Lose Weight

The recommended method of gaining or losing weight is to either increase or decrease caloric intake, respectively, by at least 500 kcalories a day. This should result in a weekly 1-pound weight gain or loss, respectively.

How Many Kilocalories Equal a Pound?

3,500 kcalories = 1 pound

To lose 1 pound = Consume 3,500 kcalories less and/or burn it off with exercise

To gain 1 pound = Consume 3,500 kcalories over what your body burns

Combination of Diet and Exercise

If a person can achieve a deficit of 500 kcalories per day through diet and/or exercise, they will lose approximately 1 pound a week.

Successful Weight Loss is Usually Slow

Consistency is the goal. The slower you lose the weight, the more likely it will stay off.

1 pound a week for 1 month = 4 weeks = 4 pounds

1 pound a week for 1 Year = 52 weeks = 52 pounds

and protein foods (Figure 1-4). The www.choosemyplate.gov website provides interactive tools to assist people in creating a personalized **food group plan** based on the *Dietary Guidelines* and taking small steps toward making better daily food and lifestyle choices.

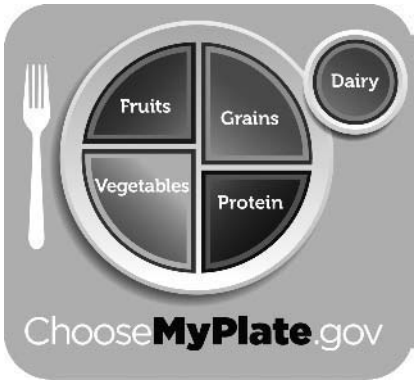
SuperTracker

The SuperTracker is an online diet and physical activity tracking tool. It is available at http://www.choosemyplate.gov/supertracker-tools/supertracker.html. Here, consumers can look up individual foods to see or compare their nutritional values, find recommendations for what and how much to eat, and compare food choices to these recommendations and their personal nutrient needs (78).

Food group plan A diet-planning tool that groups foods together based on nutrient and/or kcalorie content and then specifies the amount of each group a person should consume based on their recommended kcalorie intake.

Antioxidant A compound that inhibits oxidation, which can cause deterioration and rancidity.

FIGURE 1-4 MyPlate: A pictorial demonstration of the 2010 *Dietary Guidelines.*



Source: United States Dept. of Agriculture.

Previous Food Group Plans

MyPlate is a successor to several previous food plans, including MyPyramid (released in 2005) and the Food Guide Pyramid (1992), all developed to encourage Americans to improve their diets. One of the first food group plans was the basic four food groups of milk, meat, vegetable/fruit, and bread/cereal (28). Other countries have their own versions of food group plans; Canada's version is available online (see websites at the end of chapter) (73).

Vegetarianism

About 3 to 4% of the U.S. population does not consume meat, poultry, or seafood, and approximately 1% of adults are vegan (29), compared to approximately 15% of college students who define themselves as vegetarians. The Academy of Nutrition and Dietetics has suggested that properly planned vegetarian diets may reduce the risk of certain chronic, degenerative diseases and conditions, including heart disease, some cancers, diabetes mellitus, obesity, and high blood pressure (1). Other factors, however, may contribute to the decreased morbidity and mortality from these diseases among vegetarians. These include positive lifestyle differences such as lower rates of smoking and drinking. Nevertheless, the benefits of vegetarian diet probably come from lower intakes of fat, saturated fat, cholesterol, and animal protein, balanced by higher levels of phytochemicals, fiber, complex carbohydrates, **antioxidants** such as vitamins C and E, carotenoids, and folate (a B vitamin) (58). A 2007 World Cancer Research Fund (WCRF) and American Institute for Cancer Research (AICR) report stated that one's risk of cancer can

be reduced by maintaining a healthy weight throughout life, consuming a diet high in plant-based foods, limiting intakes of red meat, avoiding salty foods and processed meat, and consuming alcohol in modest amounts, if at all (90).

Consumer Dietary Changes

As a result of these dietary guidelines and other influences, consumers have shifted their dietary concerns and intakes, and more people are reading the Nutrition Facts on food labels to understand what they are consuming (Chapter 29). Throughout the 1990s, consumers reported that their biggest nutritional concern was fat (84). Today, Americans are ingesting less milk and more poultry, fish, fresh vegetables, and grains. As a result, fat consumption has dropped from 42% of kcalories in the mid-1960s to less than 33% today (12, 95). Despite some positive dietary trends, progress remains to be made by Americans in order to meet the *Dietary Guidelines for Americans,* as shown in Figure 1-5 (89).

Complementary and Alternative Medicine

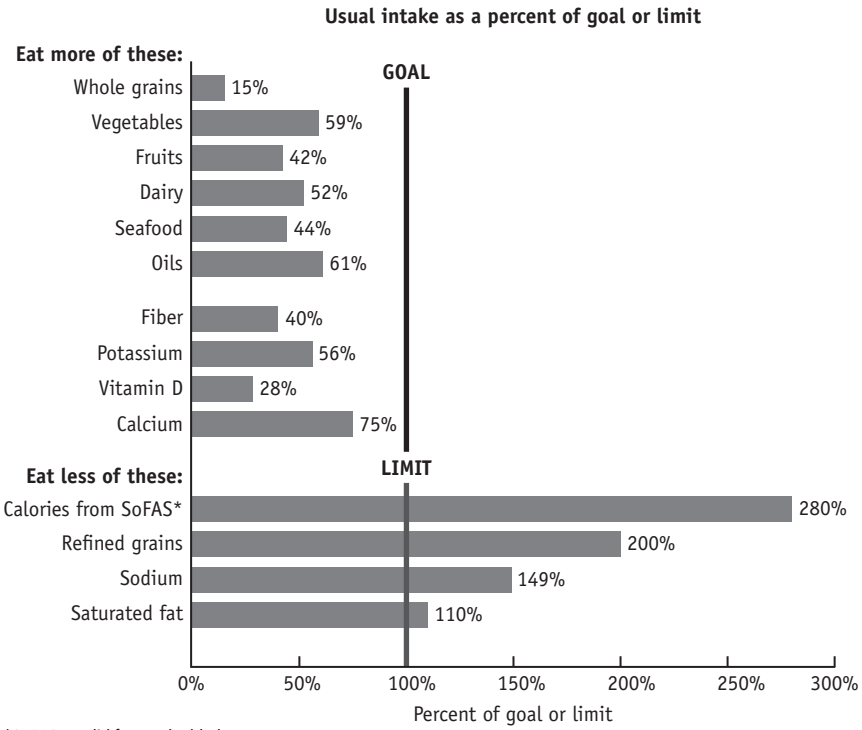
Another influence on consumer dietary changes is complementary and alternative medicine (CAM), which is making permanent inroads in the U.S. medical landscape. Terms such as **nutraceuticals** and **functional foods** (described more fully following this section) are becoming commonplace. In the United States, *nutraceuticals* is a term often used to refer to dietary supplements, while the official definition in Canada is "a product isolated or purified from foods, and generally sold in medicinal forms not usually associated with food and demonstrated to have a physiological benefit or provide protection against chronic disease" (42). About 33% of Americans have used herbs or herb products medicinally, and about 60% take a multivitamin supplement.

Europe and Japan lead the way in complementary medicine. In Germany, the E Commission was created in 1978 to ensure product standardization and safe use of herbs and phytomedicines. Composed of a body of experts from the medical and pharmacology professions, the pharmaceutical industry, and laypersons, the German E Commission studies the scientific literature for research data on herbs based on clinical trials, field studies, and case studies. It has created a collection of **monographs** representing the most accurate information available in the world on the safety and efficacy (power to produce effects or "does it work?") of herbal products. Germany defines herbal remedies in the same manner as it does drugs, because its physicians, and others in Europe, often prescribe herbal remedies that are paid for by government health insurance.

Functional Foods

Overall, more and more people are viewing foods as an integral part of maintaining their health (47). The "food is medicine" concept is common to many cultures, and the shift from treating an established disease to possibly delaying or even preventing it is slowly gaining ground globally. The functional food concept first developed in Japan in the late 1980s. In Japan, "Foods for Specified Health Use," are functional foods produced, selected, or consumed for reasons beyond basic caloric and nutrient content. Purported uses for which functional foods have been manufactured include cancer risk reduction, heart health (blood pressure and blood cholesterol levels), and maintenance of gastrointestinal health (3, 45). Both Japan and Europe appear to surpass the United States in their interest in how foods can benefit health beyond providing carbohydrates, protein, fat, and vitamins/minerals. In fact, Japan is the only country that recognizes functional foods as a distinct

FIGURE 1-5 What Americans eat versus what the 2010 *Dietary Guidelines* recommend they should eat.



*SoFAS = solid fats and added sugars.

Source: U.S. Department of Agriculture and U.S. Department of Health and Human Services. Dietary Guidelines for Americans, 2010. 7th Edition, Washington, DC: U.S. Government Printing Office, December 2010. Figure 1-5 How Do Typical American Diets Compare to Recommended Intake Levels or Limits? (p. 46).

Nutraceutical A bioactive compound (nutrient or nonnutrient) that has health benefits.

Functional food A food or beverage that imparts physiological benefits that enhance overall health, prevents or treats a disease or condition, and/or improves physical/mental performance.

Monograph A summary sheet (fact sheet) describing a substance in terms of name (common and scientific), chemical constituents, functional uses (medical and common), dosage, side effects, drug interactions, and references.

Joerg Reuther/imagebroker/Alamy

category, and its functional food market is the most advanced in the world (97).

The United States has no official definition for "functional foods," and they are not recognized as a regulatory category by the Food and Drug Administration. The largest organization of food and nutritional professionals in the United States, the Academy of Nutrition and Dietetics (AND; formerly the American Dietetic Association, or ADA), classifies all foods as functional because they provide nutrients or other substances that furnish energy, sustain growth, and/or maintain and repair the body. However, functional foods move beyond basic survival needs. They provide additional health benefits that may reduce disease risk and/or promote optimal health. Specifically, the AND defines functional foods as including conventional foods, modified foods (fortified, enriched, or enhanced), medical foods, and foods for special dietary use (Table 1-1) (41). These functional food categories—published in a 2009 ADA Position Paper—include:

1. *Conventional Foods*. Unmodified whole foods or conventional foods such as fruits and vegetables are the simplest functional foods. A few of the many examples of health benefits linked to conventional foods by emerging evidence include:

   Cancer Risk Reduction
   - Cruciferous vegetables reduce the risk of several types of cancers (67).
   - Tomato products rich in lycopene may reduce the risk of prostate, ovarian, gastric, and pancreatic cancers (51).
   - Citrus fruit may reduce the risk of stomach cancer (4).

   Heart Health
   - Dark chocolate reduces high blood pressure (24).
   - Tree nuts and peanuts reduce the risk of sudden cardiac death (57).

   Intestinal Health Maintenance
   - Fermented dairy products (probiotics) may reduce irritable bowel syndrome symptoms (79).

   Urinary Tract Function
   - Cranberry juice reduces bacterial concentrations in the urine (61).

   Some other health conditions affected by conventional foods include osteoporosis, diabetes, arthritis, brain health (mood, memory, depression, insomnia, stress, anxiety, and alertness), weight (appetite, weight loss or gain), eyesight, and enhanced energy and sports performance (61).
2. *Modified Foods*. Functional foods can also include those that have been modified through fortification, enrichment, or enhancement. These include calcium-fortified orange juice (for bone health), folate-enriched breads (for proper fetal development), and foods enhanced with bioactive components, such as margarines containing plant stanol or sterol esters (for lowering cholesterol), and beverages enhanced with "energy-promoting" ingredients such as ginseng, guarana, or taurine.
3. *Medical Foods*. The term *medical food,* as defined by the Orphan Drug Act, is "a food which is formulated to be consumed or administered enterally under the supervision of a physician and which is intended for the specific dietary management of a disease or condition for which distinctive nutritional requirements, based on recognized scientific principles, are established by medical evaluation" (27). Examples of medical foods include oral supplements in the form of phenylketonuria (PKU) formulas free of phenylalanine, and diabetic, renal, and liver formulations. How the product is marketed to consumers determines the regulatory status

TABLE 1-1 Functional Food* Categories and Selected Food Examples

Functional food category	Selected functional food examples
Conventional foods (whole foods)	Garlic
	Nuts
Modified foods	
Fortified	Calcium-fortified orange juice
	Iodized salt
Enriched	Folate-enriched breads
Enhanced	Enhanced energy bars, snacks, yogurts, teas, bottled water, and other functional foods formulated with bioactive components such as lutein, fish oils, ginkgo biloba, St. John's wort, saw palmetto, and/or assorted amino acids
Medical foods	Phenylketonuria (PKU) formulas free of phenylalanine
Foods for special dietary use	Infant foods
	Hypoallergenic foods such as gluten-free foods, lactose-free foods
	Weight-loss foods

*As defined by the Academy of Nutrition and Dietetics.

of a product. For example, a canned or bottled oral supplement used under medical supervision is a medical food; however, it becomes a food for special dietary use when sold to consumers at the retail level.

4. *Foods for Special Dietary Use*. The Federal Food, Drug, and Cosmetic Act [Section 411(c) (3)] defines *special dietary use* as "a particular use for which a food purports or is represented to be used, including but not limited to the following: (1) supplying a special dietary need that exists by reason of a physical, physiological, pathological, or other condition . . .; (2) supplying a vitamin, mineral, or other ingredient for use by humans to supplement the diet by increasing the total dietary intake, and (3) supplying a special dietary need by reason of being a food for use as the sole item of the diet. . . " (27). Examples of such foods would include infant formulas, and hypoallergenic foods such as gluten-free foods, lactose-free foods, and foods offered for reducing weight.

Although functional foods are emerging as one of the latest trends in food and nutrition, this concept is not entirely new; about 2,500 years ago, Hippocrates said, "Let food be thy medicine, and medicine be thy food" (6).

Nutrigenomics

Someday people might receive diet plans tailored to their genes thanks to **nutrigenomics,** which first appeared in the scientific literature in 2001 (74). Before the term was coined, nutrigenomics existed undefined within the study of metabolic disorders (inborn errors of metabolism). These genetic errors often occur because of the lack of an enzyme within a biochemical pathway resulting in a need for dietary intervention, as is the case with phenylketonuria (PKU). Nutrigenomics includes not only these diseases, but all others in which less dramatic genetic differences result in different dietary needs—such as heart disease, diabetes (types 1 and 2), osteoporosis, rheumatoid arthritis, hypertension, bipolar disorder, and myriad inflammatory disorders—and any other disease or condition with a genetic link that may be improved by dietary modification (16). Nutrigenomics relies on nutritional biochemistry to explain why differences in genes cause variations in absorption, circulation, or metabolism of essential nutrients. This knowledge enables people to select certain foods for optimal health or reduced risk of chronic disease (33). Some suggest that this science, still in its infancy, may take some time to contribute to human health (68).

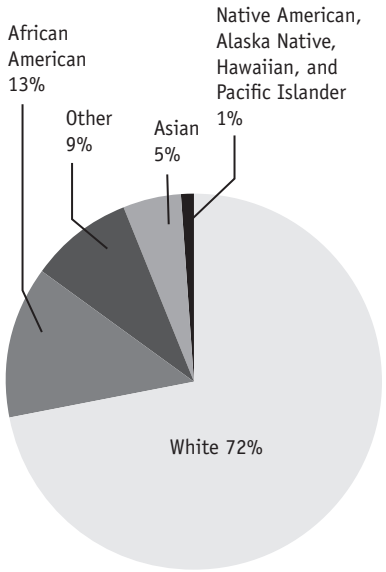
CULTURAL CRITERIA

Culture is another factor influencing food choice. Culture influences food habits by dictating what is or is not acceptable to eat. Foods that are relished in one part of the world may be spurned in another. Grubs, which are a good protein source, are acceptable to the aborigines of Australia. Whale blubber is used in many ways in the arctic region, where the extremely cold weather makes a high-fat diet essential. Dog is considered a delicacy in some Asian countries. Escargots (snails) are a favorite in France. Sashimi (raw fish) is a Japanese tradition that has been fairly well accepted in the United States. Locusts, another source of protein, are considered choice items in the Middle East. Octopus, once thought unusual, now appears on many American menus.

Ethnic Influences

Ethnic minorities comprise approximately 37% of the U.S. population of approximately 312 million people, with the five major groups being African, other (includes two or more races), Asian, Native/Alaskan Americans, and Native Hawaiian/Pacific Islanders (Figure 1-6). The U.S. Census does not classify "Hispanic" or "Latino" as a race. Rather, those taking the survey are asked whether or not they are "Spanish/Hispanic/Latino" and to select the race with which they identify. The belief is that people from this group may be of any race, but this makes the overall percentage "picture" a little confusing. The latest U.S. Census reported 16% of the American population being of "Hispanic or Latino" descent. An increasingly diverse population in the United States, accompanied by people traveling more and communicating over longer distances, has contributed to a more worldwide community, and a food industry that continues to "go global" (80). Within the boundaries of the United States alone, many foods once considered ethnic are now commonplace: pizza, tacos, beef teriyaki, pastas, and gyros. More recently arrived ethnic foods, such as Thai, Indian, Moroccan, and Vietnamese, are constantly being added to the mix to meet the escalating demands for meals providing more variety, stronger flavors, novel visual appeal, and less fat (86).

FIGURE 1-6 Percent distribution of racial/ethnic groups in the United States. Sixteen percent of Americans report themselves to be "Spanish/Hispanic/Latino."



Source: U.S. Census Bureau.

Place of Birth

Birthplace influences the foods to which a person will be exposed and helps shape the dietary patterns that

Nutrigenomics A field of study focusing on genetically determined biochemical pathways linking specific dietary substances with health and disease.

Culture The ideas, customs, skills, and art of a group of people in a given period of civilization.

are often followed for life. Salsa varies in flavor, texture, and color depending on whether it was prepared in Mexico, Guatemala, Puerto Rico, or Peru. Curry blends differ drastically depending on where in the world the recipe evolved. In Mexican cuisine, the same dish may taste different in different states.

Geography and Climate

Not so long ago, geography and climate were the main determinants of what foods were available. People ate foods that were grown close to where they lived and very rarely were presented with the possibility of eating those of a more exotic nature. For example, guava fruit grown in tropical regions was not even a consideration in an area such as Greenland. Now the wide distribution of formerly "local" foods throughout the world provides many people with an incredible variety of food choices.

Cultural Influences on Manners

Culture not only influences what types of foods are chosen, but also the way they are consumed and the behavior surrounding their consumption. In some parts of India, for example, only the right hand is used for eating and manipulating utensils; the left hand is reserved for restroom duties. Foods may be served on banana leaves or wrapped in cornhusks. It may be eaten with chopsticks, as is the custom throughout Asia, or with spoons, forks, and knives as in Europe and the Americas. It is considered impolite in China not to provide your guest with a bountiful meal, so an unusually large number of food courses is served when guests are present.

RELIGIOUS CRITERIA

Religion is another important influence on food choices. Religious beliefs affect the diets of many by declaring which foods are acceptable and which are unacceptable and by specifying preparation procedures. By designating certain foods for specific occasions and assigning symbolic value to some, religious principles wield further influence (23).

More than 76% of the American population claims to be Christian, and the bread (wafers) and wine served by many denominations during communion symbolize the body and blood of Christ. A traditional holiday meal with a turkey or ham as the main entrée is usually served at Christmas and/or Easter. The eggs used at Easter symbolize new life and were originally painted red to represent Christ's blood. Early Christians exchanged these eggs to recognize each other. Another food important to Catholics is fish, which, in the past, was served on Fridays instead of meat.

Some of the food practices of Buddhists, Hindus, Seventh-Day Adventists, Mormons, Jews, and Muslims are explored in further detail below.

Buddhism

There are over 100 million Buddhists in China and 300 million worldwide. Buddhists believe in *karuna* (compassion) and karma (a concept that implies that "good is rewarded with good; evil is rewarded with evil; and the rewarding of good and evil is only a matter of time") (46). Many Buddhists consider it uncompassionate to eat the flesh of another living creature, so vegetarianism is often followed; however, not all Buddhists are vegetarian. Whether Buddhists are vegetarian depends on their personal choice, the religious sect to which they belong, and the country where they live (22).

Hinduism

Most of the 930 million followers of Hinduism live in India, and the Hindu American Foundation estimates that there are 2 million Hindus in the United States. Like Buddhism, Hinduism also promotes vegetarianism among some, but not all, of its followers (55). Buddhism actually originated in India before being disseminated to Asia and surrounding areas. The goal of both Hinduism and Buddhism is to reach "enlightenment" or "nirvana," in which the soul transcends "individual" ego and unites with the cosmos's higher state of consciousness (sometimes described as One, Supreme God). It is believed that souls which do not reach this state on earth are reincarnated. As a result, some Hindus believe that the soul is all-important, uniting all beings as one, so it is against their beliefs to injure or kill a person or an animal. Thus, strict Hindus reject poultry, eggs, and the flesh of any animal. The cow is not considered sacred among Hindus as is widely believed, but it is an animal so it is not slaughtered for food. However, dairy products from cattle are acceptable and even considered spiritually pure (22). Coconut and *ghee*, or clarified butter, are also accorded sacred status, but may be consumed after a fast. Some strict Hindus do not eat garlic, onions, mushrooms, turnips, lentils, or tomatoes.

Seventh-Day Adventist Church

A vegetarian diet is recommended but not required for members of the Seventh-Day Adventist Church. About 40% of its members are vegetarians, the majority of them lacto-ovo-vegetarians, meaning that they allow milk and egg products (40). Consumption of between-meal snacks, hot spices, alcohol, tea, and coffee is discouraged (52).

Church of Jesus Christ of Latter-Day Saints (Mormon Church)

The Church of Jesus Christ of Latter-Day Saints discourages the consumption of alcohol, coffee, and tea. Section 89:12 of the Doctrine and Covenants written in 1833 states, "Yea, flesh also of beasts and of the fowls of the air . . . they are to be used sparingly." Although not all Mormons follow these lifestyle recommendations, several studies suggest that they are healthier as a group when compared with average Americans. A significant number of Mormons live in Utah, and several studies have shown

that the death rate attributed to specific diseases for Utah residents is 40% below the average U.S. rate because of lower rates of heart disease and cancer. Other factors possibly affecting the death rate are the discouragement of smoking and illegal drug use, the recommendations of regular physical activity and proper sleep, and a positive religious outlook (76). The lower saturated fat content of some vegetarian diets and the strength of Utah's health care system also cannot be ignored as possible contributing factors.

FIGURE 1-7 Examples of kosher and halal food symbols.

Kosher	Halal
Organized Kashruth Laboratories Brooklyn, NY	Islamic Services of America Cedar Rapids, IA
OU Kosher Supervision Service New York, NY	

Judaism

The *kashrut* (or *kashruth*) is the list of dietary laws adhered to by orthodox Jews. **Kosher** dietary laws focus on three major issues (81):

1. Kosher animals allowed
2. Blood not allowed
3. Mixing of milk and meat not allowed

Foods are sorted into one of three groups: meat, dairy, or *pareve* (containing neither meat nor dairy). Milk and meat cannot be prepared together or consumed in the same meal. In fact, separate sets of dishes and utensils are used to prepare and serve them, and a specified amount of time (1 to 6 hours) must pass between the consumption of milk and meat. Foods considered kosher include fruits, vegetables, grain products, and with some exceptions during Passover, tea, coffee, and dairy products from kosher animals, as long as they are not eaten simultaneously with meat or fowl (82). Kosher animals are ruminants such as cattle, sheep, and goats that have split hooves and chew their cud. Other meats that are considered kosher are chicken, turkey, goose, and certain ducks.

Orthodox Jews are not allowed to eat nonkosher foods such as carnivorous animals, birds of prey, pork (bacon, ham), fish without scales or fins (shark, eel, and shellfish such as shrimp, lobster, and crab), sturgeon, catfish, swordfish, underwater mammals, reptiles, or egg yolk containing any blood. These foods are considered unclean or *treif*. Even the meat from allowed animals is not considered kosher unless the animals have been slaughtered under the supervision of a rabbi or other authorized individual who ensures that the blood has been properly removed. Foods that are tainted with blood, a substance considered by Jews to be synonymous with life, are forbidden (22).

Kosher foods are labeled with a logo such as those of the kosher-certifying agencies shown in Figure 1-7. Manufacturing facilities are inspected by a rabbi before a kosher certification can be given for a food (9). People other than Jews who often purchase kosher foods include Muslims, Seventh-Day Adventists, vegetarians, individuals with allergies (shellfish) or food intolerances (milk), and anyone who perceives kosher foods as being of higher quality (82).

Food figures prominently in the celebration of the major Jewish holidays. Rosh Hashanah, the Jewish New Year, is celebrated in part with a large meal. Yom Kippur, or the Day of Atonement, requires a day of fasting preceded by a bland evening meal the night before. Passover, which is an 8-day celebration marking the Exodus from Egypt, is commemorated in part by a meal whose components represent different aspects of the historic event. The Jews left Egypt without enough time for their bread to leaven (rise); to commemorate this event, leavened bread is prohibited during the Passover celebration. As a result, the five prohibited grains are wheat, rye, oats, barley, and spelt. The only grain allowed during Passover is unleavened bread (matzo).

Islam

Worldwide, there are over 1.5 billion Muslims, versus 13 million Jews (22). The Koran, the divine book of Islam, contains the **halal** dietary food laws recommended for Muslims that describe halal (permitted) or haram (prohibited) foods (84). The five major areas addressed by the halal follow (80):

1. Kosher and halal animals allowed
2. Blood not allowed
3. Improper slaughtering method not allowed
4. Carrion (decaying carcass) not allowed
5. Intoxicants not allowed

Many of the halal dietary food laws are similar to the food laws of Judaism, and like kosher foods, halal foods are identified with symbols (Figure 1-7). However, the most striking similarity is that the kosher meat consumed by Jews is permitted for Muslims because the animal has been slaughtered in a manner that allows the blood to be fully drained. Halal meat is also permitted and defined as any meat from approved animals processed according to Muslim guidelines. Most meat is allowed, except pork, carnivorous animals with fangs (lions, wolves, tigers, dogs, etc.), birds with sharp claws (falcons, eagles, owls, vultures, etc.), land animals without ears (frogs, snakes, etc.), shark, and products containing pork or gelatin made from the horns or hooves of cattle (15). Alcohol and products containing alcohol in any form, including vanillin and wine vinegar, are forbidden.

Kosher (From Hebrew) Food that is "fit, right, proper" to be eaten according to Jewish dietary laws.

Halal An Arabic word meaning "permissible." Usually refers to permissible foods under Islamic law.

Stimulants such as tea and coffee are also discouraged.

Ramadan is a time of the year that significantly affects diet for Muslims. Islam teaches that the ninth month of the lunar calendar is the month in which the Prophet Muhammad received the revelation of the Muslim scripture, the Koran. This month, which depends on the sighting of the new moon, is a time of religious observances that include fasting from dawn to sunset.

PSYCHOLOGICAL AND SOCIOLOGICAL CRITERIA

Social and psychological factors strongly influence food habits. For most people, the knowledge that food is readily available provides a sense of security. The aim of every food company's advertising is to develop a sense of security among consumers about its products. A soft drink held in the hand of an athlete, a cereal touted by a child's favorite cartoon character, and diet foods offered by slim, vivacious spokespeople create positive associations in people's minds for these products and assure them of their quality. Social conscience and peer pressure sometimes influence food choices. One recent trend has seen consumers moving toward more environmentally sound purchases. At a buffet, the presence of other people may influence a person's choice of food and beverages.

Psychological needs intertwine with social factors when foods are used more for a display of hospitality or status than for mere nourishment. Caviar is just fish eggs, but is esteemed by many as a delicacy. Beer tastes terrible to most people when they try it for the first time, but the social surroundings and pressures may cause it to become an acquired taste. Several studies have shown that information influences expectations, and expectations mold choices (17), so it is no surprise that consumers report that television is their predominant source of information about nutrition, followed by magazines, and newspapers (6, 65).

Psychological factors also influence people's response to three relatively recent additions to the food market: genetically modified, organic, and "natural" foods.

Jeffrey Coolidge/Iconica/Getty Images

Bioengineering

Psychological and social factors are involved in the formation of public attitudes toward the **biotechnology** (i.e., genetic engineering) of foods (25). The resulting **genetically modified organisms (GMOs)** or genetically modified (GM) crops are slowly gaining ground, but not everyone is knowledgeable about or accepting of these new foods (1).

History of Biotechnology

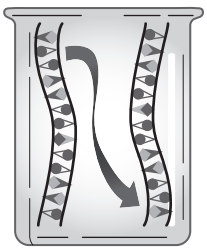
In the past, it took years to accomplish hybridization, or crossbreeding, by matching "the best to the best" in the plant, livestock, and fishery worlds to achieve the desired results. Cattle, corn, and even dogs were bred this way to yield desirable results. Dogs would not look the way they do without humans modifying their genes through many years of selective breeding. Depending on the desired results, it could take decades or even centuries to develop a certain "look" and/or function in an animal or plant. Traditional ways of breeding to combine the genes of two

Biotechnology The alteration of a gene in a bacterium, plant, or animal for the purpose of changing one or more of its characteristics; previously called *genetic engineering*.

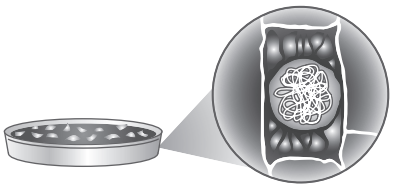
Genetically modified organisms (GMOs) Plants, animals, or microorganisms that have had their genes altered through genetic engineering using the application of recombinant deoxyribonucleic acid (rDNA) technology.

FIGURE 1-8 Genetically engineering a tomato to soften more slowly.

1. Ripe tomatoes contain an enzyme, polygalacturonase (PG), that causes them to soften. The PG gene that forms this enzyme is isolated and cloned. Scientists reverse the PG gene sequence and place it into bacteria.



2. The bacteria are grown in a petri dish filled with cut tomato leaves. The leaves' edges absorb the bacteria and the PG gene becomes part of the tomato plant cells' genetic material.



3. Tomato plants are regenerated from leaf cuttings containing the reversed PG gene.

4. The genetically engineered tomatoes can now ripen more fully on the vine prior to harvest and be transported later with less concern about rotting due to softening.

Source: Adapted from Hoban TJ. How Japanese consumers view biotechnology. Food Technology 96(5):85–88, 1996.

species in order to obtain a specific trait were thus time consuming, cumbersome, and unpredictable (63).

Along came the age of food biotechnology, which began in the early 1970s when DNA was isolated from a bacterium, duplicated, and inserted into another bacterium. The resulting DNA, known as recombinant deoxyribonucleic acid (rDNA), allows researchers to transfer genetic material from one organism to another (Figure 1-8) (43, 48). Instead of crossbreeding for years, researchers can now identify the **genes** responsible for a desired trait and reorganize or insert them from the cells of one bacterium, plant, or animal into the cells of other bacteria, plants, or animals (1). The goal of this process is to produce new species or improved versions of existing ones. GM crops have only been commercially available since the mid-1990s (63).

Foods Created with Biotechnology

The U.S. Department of Agriculture envisions food biotechnology being used to increase production potential, develop more nutritious plant and animal products (63), and increase crop resistance to the following (48):

- Pests (less pesticide required)
- Disease (lower crop losses)
- Herbicides
- Harsh growing conditions (drought, salty soil, climate extremes)
- Transport damage (less bruising allows more produce to make it to market)
- Spoilage (longer shelf life)

Foods using biotechnology can be categorized as one of the following (1):

1. Actual food (e.g., corn)
2. Foods derived from or containing ingredients of actual food (e.g., cornmeal)
3. Foods containing single ingredients or additives from GM foods (e.g., amino acids, vitamins, colors)
4. Foods containing ingredients obtained from enzymes produced through GM foods

What actual foods have been produced using biotechnology? Some examples of GM foods include ripening-delayed fruits, celery without strings, grains with a higher protein content, potatoes that absorb less fat when fried, insect-resistant apples, and more than fifty other plant products. Currently, the most popular GM crops among U.S. farmers are soybeans, corn, cotton, canola, papaya, squash, and sugar beets. More than 93% of all U.S. soybean, cotton, and sugar beets are grown from GM seeds (63).

Clones: Not GMOs Some people may think that cloned animals or plants are genetically engineered; however, that is not the case. The Biotechnology Industry Organization describes cloning as a "breeding method that does not manipulate the animal's genetic make-up nor change an animal's DNA; it is simply another form of sophisticated assisted reproduction. Cloning allows livestock breeders to create a genetic copy of an existing animal—essentially an identical twin. Animal clones are not 'biotech' or 'genetically engineered' animals; and their offspring are considered 'conventional' animals."

Concerns about Food Biotechnology

Some consumers view genetic engineering as an invasion of nature's domain, and fear that scientists are treading on dangerous ground. Their concerns include allergies, gene contamination, and religious/cultural objections.

- ***Allergies.*** The concern most commonly expressed to the Food and Drug Administration by consumers is the possibility that the proteins produced by these new genes could cause allergic reactions. In one study, soy was infused with a gene from Brazil nuts, a known allergen, or allergy-causing substance (54). Some people participating in the experiment became ill, but this was a preliminary research study and the modified soy never reached the market (71). Researchers would be prudent to avoid food allergens in the process of genetically engineering foods

Gene A unit of genetic information in the chromosome.

because they can cause significant problems for the small percentage of the population with food allergies (36).

- ***Gene Contamination.*** Another concern is that genetically engineered plants might "escape" into the wild, take over, and change the environment. Scientists assure us, however, that such plants are no more dangerous than traditionally bred crops. The greatest fear for some is that food biotechnology will lead to genetic manipulation to try to "improve" the human race (54).
- ***Religious/Cultural Concerns.*** Some people, for religious or cultural reasons, do not want certain animal genes appearing in plant foods. For example, if swine genes were inserted into vegetables for some purpose, those vegetables would not be considered kosher. In one instance, a group of chefs refused to use a genetically engineered tomato when they found out that its disease resistance was obtained from a mouse gene. Vegetarians may object to a fish gene being placed in a tomato to provide resistance to freezing (43). Hawaiians objected when researchers tried to modify the gene sequence of their sacred taro plant, which is commonly used to make poi (a starchy paste made from the plant's corm, its thickened underground stem).

Acceptance/Rejection of GM Foods

Despite the controversy over animal genes being inserted in plant foods, the line between "plant genes" and "animal genes" is already blurred. Bacteria, plants, and animals share a large number of the more than 100,000 genes found in higher organisms. Nevertheless, research into people's attitudes about food repeatedly reveals that consumers are more likely to accept biotechnology conducted on plants rather than on animals or fish (44).

The Food and Drug Administration accepts genetically engineered foods as posing no risk to health or safety, and for this reason it does not require mandatory labeling, unless the foods contain new allergens, have modified nutritional profiles, or represent a new plant. The National Academy of Sciences has stated that genetic transfers between unrelated organisms do not pose hazards or risks different from those encountered by natural selection or crossbreeding. Currently, there is no evidence that transferring genes will convert a harmless organism into a hazardous one (48). Few long-term experiments regarding the effects of biotechnology on human health have been conducted, and the topic is controversial (75). People who wish to avoid GM crops can ensure that their foods are free of this type of genetic modification (and produced without antibiotics, hormones, or pesticides) by purchasing organic foods (32, 60).

Organic Foods

Some people prefer to select *organic foods*, a term that had no official definition until 2002, following the Organic Foods Production Act of 1990 (97). This act created the U.S. National Organic Standards Board (NOSB), which in turn makes organic definition recommendations to the National Organic Program (located in the USDA's Agricultural Marketing Service). Terms commonly used in the marketplace that do not have official definitions or certification by the government include "free-range," "hormone-free," "natural," "organically produced," "pesticide-free," "raised without antibiotics," or even "certified organic." Prior to 2002, products were often labeled "organic" by growers without any real certification, or they were certified by private agencies according to a patchwork of regulations that varied from state to state. Now, for a food to be labeled "organic," it has to fit one of the four official definitions listed by the U.S. Department of Agriculture (USDA), as shown in Table 1-2. The USDA's definition of what is organic goes beyond just describing foods that are not sprayed with chemicals. The word *organic* now refers to food products that have been produced without most synthetic pesticides and fertilizers (including sewage sludge); crops that have not been genetically modified (no GMOs or bioengineering); food products not exposed to irradiation; and livestock produced without antibiotics or hormones, raised on 100% organic feed, allowed to graze on pasture at least 4 months of the year, and provided with 30% of their feed through grazing (87). Organic milk is derived from cows that have

TABLE 1-2 The U.S. Government's Criteria for Defining Organic Food Products

What does the label mean? The USDA Organic seal tells you a product is at least 95% organic.

Organic Term	Definition	Labeling Allowed
100% Organic	All ingredients of the finished product are certified 100% organic.	USDA ORGANIC
Organic	95% of finished product ingredients meet organic criteria.	USDA ORGANIC
Made with Organic Ingredients	70% of finished product ingredients meet organic criteria.	"Made with Organic Ingredients"
Contains Organic Ingredients	Less than 70% of finished product ingredients meet criteria.	May only list organic ingredients on the information panel.

not been treated with antibiotics or hormones such as recombinant bovine somatotropin (rBST) to facilitate production (64).

One concern related to organic foods is the cost to consumers, as they are typically more expensive than their conventionally grown counterparts. Another is that some proponents mislead the public with "scare tactics," suggesting that only organic foods and beverages are healthy or safe. A concern for organic advocates is that in 2007 the USDA allowed 38 nonorganic ingredients into foods that were 95% or less organic. This list includes whey protein concentrate, gelatin, 19 food colorings, two starches, unmodified rice starch, sweet potato starch, konjac flour, intestinal casings for hot dogs, fish oil, wakame seaweed, fructooligosaccharides, and some flavor-providing items such as chipotle chili peppers, celery powder, dill weed oil, chia, frozen lemon grass, Turkish bay leaves, unbleached orange shellac, frozen galangal (citrus flavor from a rhizome), and hops for beer (87).

Organic Certification

The government agency certifying that a food is organic is the USDA. A USDA certifier inspects the facilities where the food is grown, determines whether organic standards were met, and if so, allows the producer to label food products with the organic seal shown in Figure 1-9. Both 100% and 95% organic products may use the USDA organic seal, while those made with less than 95% organic ingredients may not (see Table 1-2). USDA agents determine whether food is organic by following the guidelines set by the USDA's Agricultural Marketing Service (AMS), published as the National Organic Program (NOP) in the *Federal Register* (December 21, 2000). Producers selling less than $5,000 in organic products are exempt from certification, but they must still follow the standards (87). Only food products that were organically grown or processed and certified by an accredited USDA organic–certifying agent can carry the organic seal. Violators making false claims can be fined $10,000 per offense.

"Natural" Foods

The word *natural* on a food label may or may not mean anything about how the food was produced or what it contains. This is because *natural* has no official definition in the United States except for when it is used to describe meat, poultry, and eggs overseen by the USDA. *Natural* is defined by the USDA for its products by answering two questions: (1) Does the product contain any artificial or synthetic ingredients, such as a chemical preservative? (2) Are the product and its ingredients only minimally processed? The product is natural if the answer to the first question is no, and the answer to the second question is yes (26). The lack of an official definition for *natural* for all other foods and beverages can lead to inconsistent claims and consumer confusion.

Processed Foods

Some people who select natural foods may also prefer to avoid processed foods. The term *processed* is often used to refer to highly refined packaged foods, but technically, any food changed beyond its raw state has been "processed." The International Food Information Council has divided processed foods into the following five categories (30):

- Minimally processed foods (e.g., washed and/or packaged fruits and vegetables)
- Foods processed for preservation (e.g., canned or frozen fruits and vegetables)
- Mixtures of ingredients (e.g., cake mixes, salad dressings)
- Ready-to-eat foods (e.g., breakfast cereals, lunch meats, carbonated beverages)
- Convenience foods (e.g., frozen meals and pizzas)

BUDGETARY CRITERIA

Cost is a very important limiting factor in food purchasing. In fact, the monetary values of debit cards obtained through the U.S. Department of Agriculture's Supplemental Nutrition Assistance Program (SNAP) are limited by the "Thrifty Food Plan" that calculates what an average family needs to spend on food (91).

Cost helps determine the types of foods and brands that are bought and the frequency of restaurant patronage. People feeling financial strain may still eat beef, but they may choose ground beef over prime rib. "Can I afford this?" is a question that also applies to time, which can make convenience foods effectively more economical, even if the dollar price is higher. Budgeting and time management are discussed in greater detail in Chapter 6.

FIGURE 1-9 USDA's official organic seal.

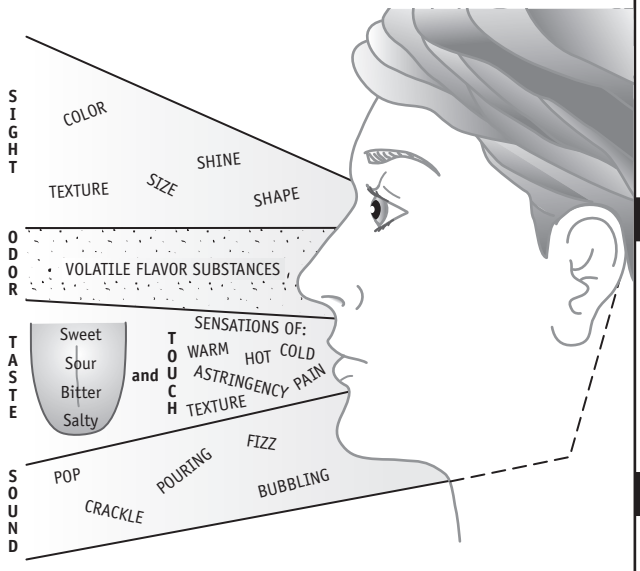
USDA

PICTORIAL SUMMARY / 1: Food Selection

People choose foods that satisfy their senses of sight, smell, taste, touch, and hearing, their nutrient needs, cultural and religious values, psychological and social influences, and budget.

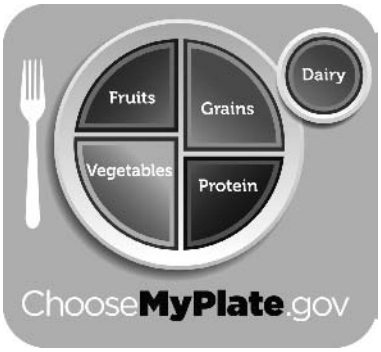
SENSORY CRITERIA

When most people choose a particular food, they evaluate it using the sensory reactions illustrated below rather than by considering its nutritional content.



NUTRITIONAL CRITERIA

Over the past several decades, emerging awareness of health and nutrition has resulted in many consumers making a major change in their diets. Guidelines that reinforce an emphasis on better health through nutrition include the U.S. Government's *Dietary Guidelines* and MyPlate food guide. Portion control starts with understanding average daily caloric intakes. Although no official U.S. regulatory definition for functional food exists, the AND defines them as conventional foods, modified foods (fortified, enriched, or enhanced), medical foods, and foods for special dietary use.



CULTURAL AND RELIGIOUS CRITERIA

An increasingly diverse population, with greater access to travel and expanded global communication, has resulted in a huge increase in the variety of foods that are available in the United States today. Familiar taste preferences acquired in childhood as well as religious tenets affect many people's food habits throughout their lives.

PSYCHOLOGICAL AND SOCIOLOGICAL CRITERIA

Advertising, social conscience, and peer pressure can all play a part in an individual's food choices. The controversies surrounding genetically modified, organic, "natural," and processed foods are examples of how food products can be affected by these criteria.

BUDGETARY CRITERIA

Cost helps determine the types of foods and brands that are bought and the frequency of restaurant patronage. A shortage of time for food preparation or consumption can result in greater use of convenience foods and "fast foods," even if they are often more expensive and less nutritious.

CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. The word *olfactory* is most closely related to which of the following senses?
   a. Taste
   b. Smell
   c. Touch
   d. Sight

2. The definition of *flavor* is best described as:
   a. taste.
   b. taste and mouthfeel.
   c. taste and odor.
   d. taste, odor, and mouthfeel.

3. Which of the following religions encourage(s) a vegetarian diet?
   a. Buddhism
   b. Hinduism
   c. Seventh-Day Adventist
   d. All of these

4. Identify the correct statement about genetically modified foods.
   a. Genes are programmed by sequencing the amino acids.
   b. Food can be genetically modified to delay ripening.
   c. In the United States, all genetically modified foods must be labeled.
   d. Not a single genetically modified food has been approved by the FDA.

5. Which of the following functional food examples is categorized as a medical food?
   a. Tomatoes rich in lycopene
   b. Gluten-free foods
   c. Folate-enriched breads
   d. Phenylketonuria (PKU) formulas free of phenylalanine

*See p. AK-1 for answers to multiple choice questions.

6. How many kcalories equal a pound of body weight?
   a. 500
   b. 1,000
   c. 2,500
   d. 3,500

7. A produce grower may place the USDA Organic label on a product if _____ or more of the ingredients are organic.
   a. 50%
   b. 75%
   c. 85%
   d. 95%

Short Answer/Essay

1. List the five taste stimuli and the proposed mechanism of taste for each.
2. Why is the odor of just-baked bread more intense than the odor of cold foods such as ice cream?
3. Give two examples of taste interactions.
4. How does taste differ from flavor?
5. Obesity is a rising problem. Discuss the basics of the energy balance equation.
6. List four categories of functional foods as defined by the Academy of Nutrition and Dietetics.
7. Discuss three examples of cultural influences on food intake.
8. Discuss the possible influences that religions such as Buddhism, Judaism, and Islam may have on food intake.
9. Describe the process of biotechnology. Discuss the pros and cons of this process.
10. Describe the four categories of organic food and the labeling allowed for each category.

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USEFUL WEBSITES

Find more information on the USDA's Dietary Guidelines:

www.health.gov/DietaryGuidelines

Find more information on the USDA's ChooseMyPlate:

www.choosemyplate.gov

Canada's Food Guide at:

http://www.hc-sc.gc.ca/fn-an/food-guide-aliment/index-eng.php

Find details about the USDA's Thrifty Food Plan:

www.cnpp.usda.gov/usdafoodplanscostoffood.htm

Calculate your body mass index (BMI) at:

www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/english_bmi_calculator/bmi_calculator.html

Learn about the statistics on different ethnic groups in the United States and your state:

www.census.gov

Find the latest obesity trends state by state from the Centers for Disease Control and Prevention (CDC) at:

www.cdc.gov/obesity/data/adult.html

Discover more about the National Organic Program (NOP) from the USDA's website on the subject:

www.ams.usda.gov/nop

Attend free flavor classes (travel and lodging not included) from FONA International at:

www.fona.com/flavor-university

Find more information about food and nutrition from the USDA's Food and Nutrition Information Center (FNIC) located at the National Agricultural Library (NAL):

http://fnic.nal.usda.gov

Find information about complementary and alternative medicine from the National Institutes of Health:

http://nccam.nih.gov

Learn more about herbal products from the Memorial Sloan-Kettering Cancer Center:

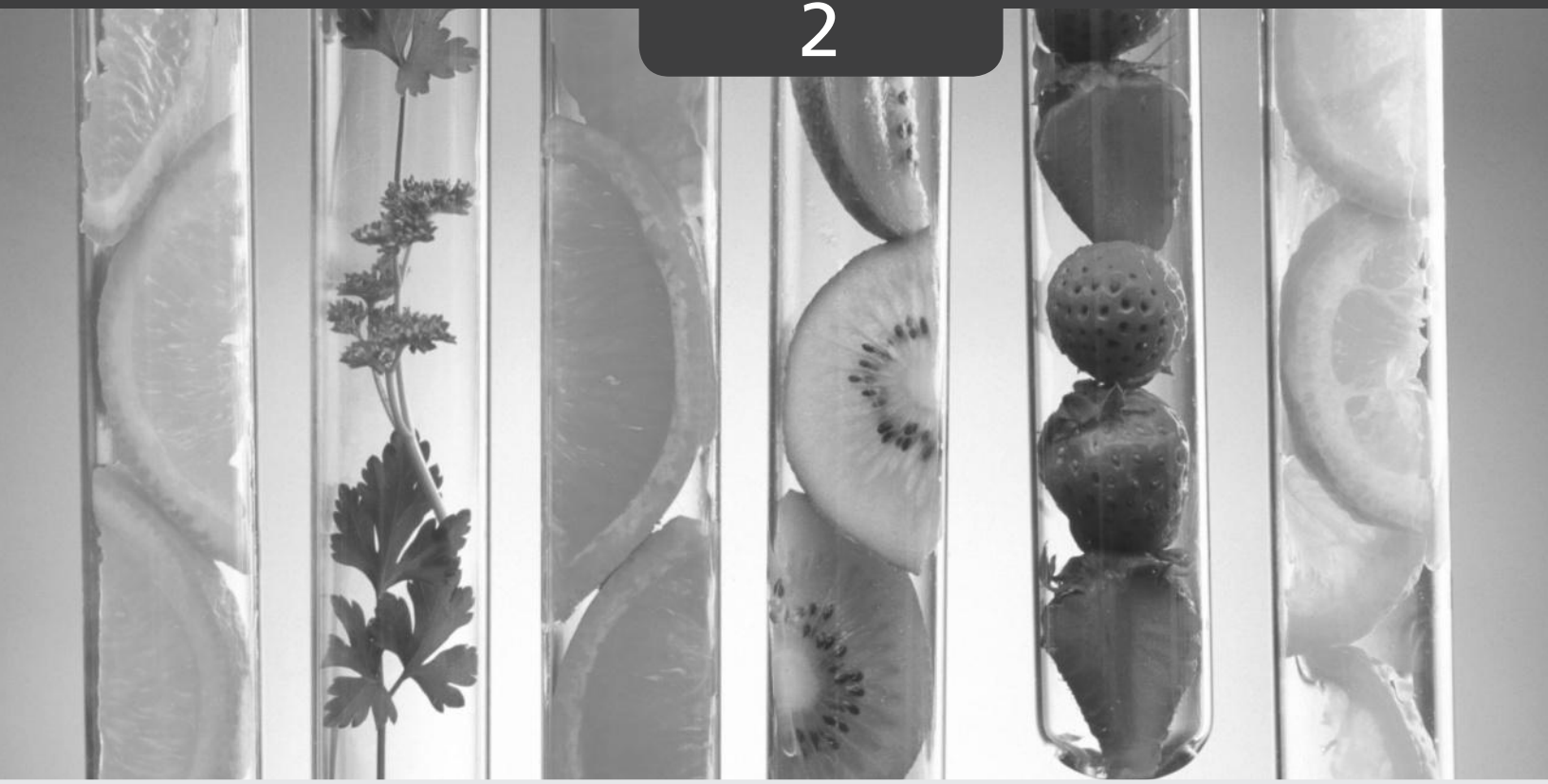
www.mskcc.org/cancer-care/integrative-medicine/about-herbs-botanicals-other-products

Explore the USDA site on Plants and Crops: Biotechnology, Genetics, and Breeding:

www.nal.usda.gov/plants-and-crops/biotechnology-genetics-and-breeding

Note: Website page links frequently change, so if a particular URL does not bring you to the desired website, just enter the key words from the description into a search engine.

2



Oscar Burriel/Photo Researchers, Inc.

Food Evaluation

The food industry uses many testing methods to measure the sensory factors used to select foods and evaluate food quality. These tests are conducted for research and development (R&D), product improvement, sales and marketing, quality assurance, nutrient content analysis for labeling requirements (Nutrition Facts), and detection of contamination or adulteration (6). Food is evaluated using both **sensory (subjective) tests** and **objective tests** (5). This chapter reviews the specific types of tests and tools used by the food industry to evaluate the palatability of food for consumers.

SENSORY (SUBJECTIVE) EVALUATION

Sensory evaluation (or analysis) is the scientific discipline of measuring the responses of people to food products as perceived by their senses of sight, taste, touch, smell, and hearing (3). This type of testing is termed *subjective* because it relies on the opinions of selected individuals.

Although certain machines are designed to replicate the ability to perceive the five senses, very few succeed in matching the senses of a human being. As a result, sensory evaluation tests are often used by large food companies in their research and development departments for the purposes of evaluating potential and/or established consumer products. Human panels are required to evaluate the products through various types of established scientific sensory tests. The results are then statistically analyzed to determine consumer preference and/or acceptability.

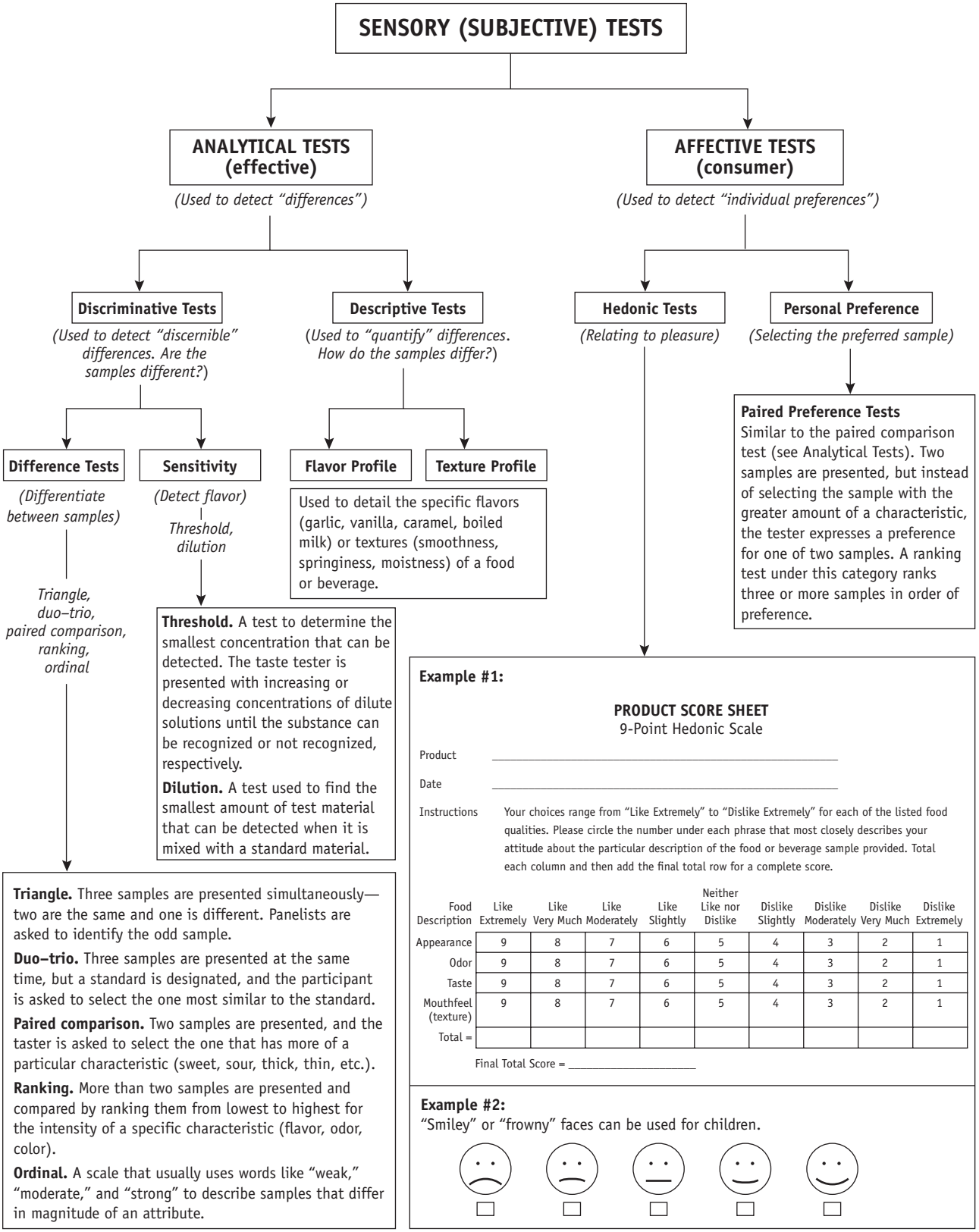
Two Types of Sensory Testing

The two basic types of sensory tests are analytical (effective) and affective (also known as acceptance or preference tests) (2). Analytical tests are more objective and based on discernible differences, whereas affective tests are more subjective and based on individual preferences (Figure 2-1). Generally, affective

Sensory (subjective) tests Evaluations of food quality based on sensory characteristics and personal preferences as perceived by the five senses.

Objective tests Evaluations of food quality that rely on numbers generated by laboratory instruments that are used to quantify the physical and chemical differences among foods.

FIGURE 2-1 Summary of subjective tests for food evaluation.



testing is carried out using a large number of untrained consumers to find out whether a particular population segment prefers one product over another. Analytical tests are conducted using smaller groups of people who may or may not be trained. In both types of testing, food samples are presented to taste panel participants, who evaluate the foods according to specific standards for appearance, odor, taste, texture, and sound.

Analytical (Effective) Tests

The more objective analytical tests are usually conducted by a trained panel that evaluates food products through either discriminative (Are the samples different?) or descriptive tests (How much do the samples differ?). The most common difference tests are the triangle and duo–trio tests, in which the person compares three samples and has to determine whether a difference exists (11). Descriptive tests rely on a trained panel to document a product's sensory characteristics (10).

Affective (Acceptance or Preference) Tests

Whether or not a person prefers a certain aspect of a food is the focus of affective or consumer testing. Because anyone can have an opinion, these types of tests are usually given to untrained consumers. Basically, affective test subjects are asked to state their opinion of a product or to rank samples in order of preference. The test instruments range from simple questions (Which of the two samples do you prefer?) to complex 9-point hedonic product score sheets evaluating one or more qualities of a food on a scale from "like extremely" to "dislike extremely" (Figure 2-1).

Taste Panels

The individuals on a taste panel can range from randomly selected members of the population to experts who are highly trained in tasting a particular food or beverage (Figure2-2) (16). Vintners and brewers rely on the latter types of skilled tasters to evaluate the proper timing for each step in the process of making wine or beer (16). The ability to detect slight differences in specific foods is a sought-after trait, prized so much that the taste buds of one gourmet ice cream taste expert are insured for $1 million. General taste panels usually consist of at least five people who meet the following criteria: they are free of colds, chew no gum immediately before testing, have not ingested any other food for at least 1 hour before testing, are nonsmokers, are not color blind, and have no strong likes or dislikes for the food to be tested. Any psychosocial or cultural influences should also be considered (4). An equal distribution in gender is preferred, because women can usually detect sweetness better than men can. Age distribution of the panel is also considered, because it may affect test results. As far as possible, panelists are representative of the consumers who will be using the product. For example, a product marketed to people over fifty should be tested by individuals in that group, whereas a product aimed at children is tested by a much younger group.

FIGURE 2-2 Taste test panel at NASA.

NASA

Sample Preparation

The environment in which the taste panel evaluates foods or beverages is also carefully controlled (19). Panelists may be

FIGURE 2-3 Testers evaluating samples in private booths that minimize outside influences.

AP Photo/Al Behrman

seated at tables, in cubicles (Figure 2-3), or in booths, and the food is presented in a uniform fashion. Food samples must be of the same size (enough for two bites), from the same portion of the food (middle vs. outside), equally fresh, at the same temperature, and presented in containers or plates that are of the same size, shape, and color. White or clear containers are usually chosen so as not to influence panelists' perceptions of the food's color. If samples differ in color, red lighting may be used to mask those differences so that color intensity will not influence the tasters' perception of flavor (16).

Care is taken that the lighting in the room is uniform, the ambient temperature is comfortable, and the surroundings are quiet and odor-free. Midmornings or midafternoons are considered the best times for sampling, because at these times people are not usually overly hungry or full. Samples are randomly coded and are kept to a reasonable number to avoid "taste fatigue." Room-temperature water and plain bread or salt-free crackers are made available for panelists to eat between samples to prevent carryover tastes, and at least a 30-second rest period is scheduled between samples. Because swallowing the food or beverage influences the taste of subsequent samples, small containers into which samples may be spit are provided, along with paper towels or napkins.

OBJECTIVE EVALUATION

In objective evaluations, laboratory instruments instead of humans are used to measure the characteristics of foods quantitatively. Most objective food evaluation is based on two major types of tests, physical and chemical, which sometimes attempt to mimic the five senses. These tests analyze for the presence of potentially harmful bacteria, yeast, and mold; create standards for maintaining quality control; and identify almost any chemical in foods used for nutrition labeling, moisture-content analysis, and detection of allergens or toxins, to name just a few examples.

Volume A measurement of three-dimensional space that is often used to measure liquids.

Density The concentration of matter measured by the amount of mass per unit volume. Objects with a higher density weigh more for their size.

Viscosity The resistance of a fluid to flowing freely, caused by the friction of its molecules against a surface.

Physical Tests

Physical tests measure certain observable aspects of food such as size, shape, weight, **volume, density,** moisture, texture, and **viscosity** (Chemist's Corner 2-1 and 2-2) (13). Instruments used vary from simple to complex (Table 2-1). For example, viscosity may be measured using a simple line-spread test, the observation of the distance a certain amount of food spreads on a surface, or with a Brookfield viscometer, a sophisticated instrument that more precisely measures viscosity under controlled

CHEMIST'S CORNER 2-1

Viscosity

Evaluation of certain foods is based on a branch of physics called rheology, which is the study of the flow and deformation of matter (both liquids and solids). Viscosity is a key term in rheology. The nature, concentration, and temperature of a liquid all affect its viscosity, which can be defined as apparent or relative. Apparent viscosity is the time required for a substance like ketchup to flow between two marks on the stem of a funnel. Relative viscosity compares the rate of a liquid's flow against a reference liquid (usually water). The thickness of fluids can determine, for example, how easily dip is deposited on chips, how smoothly mayonnaise spreads onto a slice of bread, or how long a tomato will hold its shape.

CHEMIST'S CORNER 2-2

Analyzing Food with Chromatography

Compounds in foods can be measured using chromatography (*chrom* means color). It was first used at the turn of the century to separate plant pigments into different colored bands on a spectrum. In chromatography, a moving phase (gas or liquid) is passed over a solid or liquid stationary phase (9). The constituents in a mixture are chemically separated when they adsorb onto the material of the stationary phase, which can be silica, glass, or alumina packed on a glass or metal tube.

Gas chromatography measures the contents of the gas produced when a food sample is injected into the unit and vaporized. Substances separate and travel down a very narrow column, where, as in a race, the smaller, quicker molecules arrive first and the larger ones finish last. This method is used to detect pesticides, cholesterol, certain fatty acids, and additives. In liquid chromatography, a liquid is created by making a solution out of the food sample. High-performance liquid chromatography (HPLC) is used to measure carbohydrates, lipids, vitamins, acids, pigments, flavor compounds, additives, and contaminants in food samples (minerals are commonly analyzed using atomic absorption) (1). Ion chromatography relies on ions being exchanged back and forth to detect sulfate, nitrate, and organic acids in fruit juices; and bread additives (benzoate, bromate) and sugar in various foods. Mass spectrometery takes the molecules leaving the gas chromatograph and breaks them down into ions. The pattern of ions unique to each chemical is used to identify the substance.

TABLE 2-1 Selected Physical Tests for Food Evaluation

Visual Evaluation	
Microscope	Used to observe microorganisms as well as starch granules, the grain in meats, the crystals of sugar and salt, the fiber in fruits and vegetables, and for any texture changes in processed foods.
Colorimeter	Measures color by passing a light through a substance and measuring its absorbance and/or transmittance.
Spectrophotometer	Measures color by detecting the amount and wavelength of light transmitted through a solution (14). Same principle as a colorimeter, but can measure more than one wavelength, and not just in the visible range. Spectroscopy is based on the principle that the molecules in foods and beverages will absorb light at different wavelengths on the spectrum. The amount of absorption parallels the amount of substance found in the sample. Spectroscopy can be used to determine the amount of caffeine in coffee or the concentration of riboflavin (vitamin B_2) in milk.
Weight/Volume Measurements	
Weight	Weight is measured in pounds/ounces or milligrams/grams/kilograms.
Volume	Volume quantifies the area occupied by a mass, whereas density is the measure of mass (weight) in a given volume. Specific density relates a substance's density to an equal amount of water.
Texture Measurements	
Penetrometer	Simulates teeth biting into a food to measure its tenderness.
Warner–Bratzler Shear	Evaluates meat and baked product tenderness by measuring the force required to cut through a cylindrical sample.
Shortometer	Measures tenderness by determining the resistance of baked goods, such as cookies, pastries, and crackers, to breakage. Puncture testing evaluates the firmness of fruit or vegetable tissue.
Viscosity Measurements	
Line-spread test	Measures the consistency of batters and other viscous foods. Food is placed in a hollow cylinder in the middle of the spread sheet; the cylinder is then lifted, allowing the food to spread, and the spreading distance is measured in centimeters.
Viscometer (or viscosimeter)	Measures the viscosity of food such as pudding, sour cream, salad dressing, sauces, cream fillings, cake batters, and ketchup.
Concentration Measurements	
Polarimeter	Measures the concentration of various organic compounds, especially sugars, in solution by determining the angle (refractive index) of polarized light passed through the solution. Refractometers, a type of polarimeter, are commonly used to measure sugar concentrations in soft drinks. The Brix/acid ratio is used to measure the palatability of fruit juices that depends on the delicate balance between sweetness (sugars) and tartness (acid). This ratio is obtained by measuring the degrees Brix (determined by the use of a refractometer) divided by the total acid concentration (determined by acid titration) (7, 8).
Atomic absorption	Used to measure mineral content.
Moisture analyzer	Determines water content of a product by measuring weight loss on drying (12).

FIGURE 2-4 Texture analyzer.

Food Technology Corporation

temperatures. Instruments (Figure 2-4) are available to measure many aspects of food texture, such as crispness, hardness, tenderness, crumbliness, firmness, compressibility, elasticity, and plasticity, and may come equipped with several attachments, allowing measurement of multiple attributes. For example, depending on the attachment used, the Instron Universal Testing Machine can measure the compressibility of bread or the force required to break a cookie or shear a piece of meat. Physical test instruments are sometimes purchased by companies that need to ensure that their products meet certain quality control guidelines.

Chemical Tests

The number of chemical tests available for use on foods is almost limitless, but Table 2-2 lists some of them. Many are based on the work of the Association of Official Analytical Chemists (AOAC) International, which publishes a book on chemical tests, including those for determining various nutrient and nonnutrient substances in foods.

Chemical tests can be conducted within a corporation, but they can also be sent out to commercial food testing companies. These food laboratories specialize in certain tests, such as the microbial evaluation often necessary for food safety testing. Many companies analyze their food products for certain bacteria, yeast, and/or molds. Food testing companies can also provide corporations with Nutrition Facts labels by analyzing the nutrients in a new food product. The potential for contamination and adulteration is another reason why a food company or government agency tests a food; pesticides, herbicides, and industrial residues are just a few

TABLE 2-2 Selected Chemical Tests for Food Evaluation

Benedict and Fehling tests	Determine the presence of sugars (reducing) such as lactose and maltose, which are more likely to be involved in a chemical reaction that turns food brown.
Chromatography	See Chemist's Corner 2-2. Gas chromatography is the primary technique used in flavor analysis because most of these substances are volatile. Liquid chromatography is also used in flavor testing, especially for sugars, protein fragments (umami), and other substances (15).
Electrophoresis	Specific proteins are characterized by passing an electrical field through a gel containing proteins and measuring the rates at which the proteins migrate.
Enzyme tests	The peroxidase 1 test evaluates peroxidase enzyme activity in pasteurized foods: if the heat of pasteurization is adequate to destroy harmful bacteria, it should also inactivate the peroxidase enzyme. The effectiveness of briefly boiling food to destroy the enzymes responsible for vegetable deterioration can be determined by measuring the catalase enzyme activity.
Fuchsin test	Detects aldehydes in fats and oils.
Iodine value test	Measures the degree of unsaturation in fats.
Peroxide value test	Measures the extent of oxidation within a fat.
pH meter	Detects the amount of acidity or alkalinity in food mixtures or beverages.
Proximate analysis	A sequence of chemical tests to determine the macronutrient (protein, fat, carbohydrate) content of food.

Source: U.S. Department of Agriculture.

of the chemicals that can be analyzed. For example, after melamine was illegally used in pet food by certain Chinese manufacturers to elevate protein content, the Food and Drug Administration (FDA) and some private manufacturers began analyzing for melamine (17). Table 2-3 lists the chemical analysis services offered by one food laboratory.

TABLE 2-3 Examples of Chemical Tests Conducted by a Food Testing Company

Allergens	Maximum internal temperature
Ammonia	Moisture/protein ratio
Ash	Nitrate
Calcium	Nutritional analysis and labeling
Calories (by calculation)	Percent bone
Calories from fat	Oxidative rancidity
Carbohydrates (by calculation)	Pesticide residue
Collagen	pH
Crude fiber	Phosphate
Fat (Soxhlet)	Protein
Fatty acid content (saturated, unsaturated, trans)	Salt
Iron	Sodium nitrite
Heavy metals	Soy protein concentrate
Hydroxyproline	Thiobarbituric acid reactive substances (TBA)
Moisture (water)	Unknown compound identification

Source: http://www.abcr.com/ana_meat.asp

Electronic Noses

A new and emerging technology in the field of objective evaluation is the electronic nose, or e-nose. Scientists are developing electronic nose instruments that detect certain chemicals responsible for aroma. An advantage of these devices is that they avoid some drawbacks of human noses, such as testing fatigue, subjectivity, great expense, and slow evaluations. The electronic nose can detect how well wines, beers, and spirits have aged; the quality of wheat and baked goods; the presence of bacterial contamination; coffee freshness; and even the best picking date for peaches (18).

Comparison of Sensory and Objective Evaluations

Sensory testing is expensive and time consuming, because many individuals are required to test a single product. However, it is vital for product research and development, since the consumer is the only true judge of the acceptability of a food and predictor of its marketplace success. On the other hand, objective methods are essential for routine quality control because they can produce quantitative measurements human senses cannot. Objective testing offers many advantages: it is reliable and repeatable, is not affected by human variability, and is generally faster, cheaper, and more efficient than sensory testing.

To truly evaluate food quality, both sensory and objective tests are necessary, because one cannot substitute for the other; in fact, they are complementary. Thus, the need to evaluate food quality opens up a world of exploration in food evaluation that is a rich array of both sensory and objective testing. Food corporations, certain government agencies, nutrition and food university departments, culinary schools, food marketing companies, and even individuals making daily food choices all use the principles of food evaluation.

PICTORIAL SUMMARY / 2: Food Evaluation

Food manufacturers use both sensory (subjective) and objective evaluation methods to help in determining consumer acceptance of new products in research and development (R&D), product improvement, sales and marketing, quality assurance, analysis of nutrient content for labeling requirements (Nutrition Facts), and detection of contamination or adulteration.

Sensory (subjective) tests evaluate food quality by relying on the sensory characteristics and personal preferences of selected individuals. Taste panels, consisting of either randomly chosen members of the population or experts trained in tasting a particular product, are used to conduct subjective tests:

- *Analytical tests* are based on discernible differences.
- *Affective tests* are based on individual preferences.

NASA

Objective tests rely on laboratory methods and equipment to evaluate foods through physical and chemical tests.

- *Physical tests* measure certain observable aspects of food such as size, shape, weight, volume, density, moisture, texture, and viscosity.
- *Chemical tests* are used to determine the various nutrient and nonnutrient substances in foods.

CHAPTER REVIEW AND EXAM PREP

Multiple Choice*

1. Which of the following is an example of a subjective food evaluation test?
   a. Triangle test
   b. Spectrophotometry
   c. Measuring volume
   d. Measuring weight

2. Which of the following is an example of a chemical test?
   a. Duo–trio
   b. Threshold
   c. Nutrient analysis
   d. Shortometer

3. In what analytical sensory test is a tester asked to find the minimal detectable level of a substance?
   a. Triangle
   b. Flavor profile
   c. Hedonic
   d. Dilution

4. A line-spread test is a physical test for measuring
   a. sweetness.
   b. meat and baked product tenderness.
   c. consistency of batters and other viscous foods.
   d. degree of unsaturation in fats.

5. A food evaluation in which panelists' responses range from "like extremely" to "dislike extremely" is best described as a _____ test.
   a. discriminative
   b. descriptive
   c. hedonic
   d. personal preference

6. Which chemical test evaluates the degree of unsaturation in fats?
   a. Electrophoresis
   b. Enzyme test
   c. Iodine value test
   d. Proximate analysis

7. What method is used to determine the protein, fat, and carbohydrate content of foods?
   a. Proximate analysis
   b. Fuchsin test
   c. Benedict and Fehling tests
   d. Peroxide value test

*See p. AK-1 for answers to multiple choice questions.

Short Answer/Essay

1. Describe the difference between sensory (subjective) and objective evaluation of foods.
2. How do discriminative and descriptive tests differ from one another?

3. Create a product score evaluation sheet for a cookie based on a 9-point hedonic scale.
4. Describe the general requirements for setting up a taste panel and the process of preparing samples to be subjectively tested.
5. List and describe three examples of difference testing.
6. List and describe three examples of physical testing.
7. List and describe three examples of chemical testing.
8. Describe viscosity and how it is used to test food quality.
9. How is chromatography used to evaluate certain foods?
10. Describe how a polarimeter and the Brix/acid ratio are used to test sweetness in liquids.

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USEFUL WEBSITES

The Sensory Science Laboratory at Oregon State University is just one example of a university food science department providing sensory testing services to the food industry.

http://oregonstate.edu/dept/sensory

AOAC International is a nonprofit association founded in 1884 in part to provide consensus on chemical analysis methods.

http://www.aoac.org

Complimentary classes on flavors are offered by Fona International.

http://www.fona.com/flavor-university

A specific gravity–to–degrees Brix table:

http://www.fermsoft.com/gravbrix.php

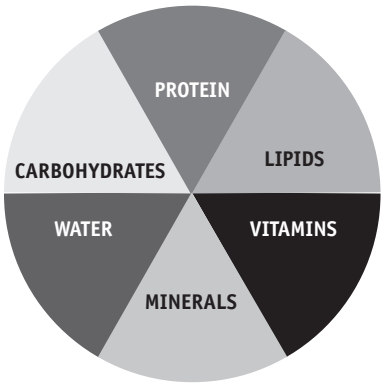
3

PhotoDisc/Getty Images

Chemistry of Food Composition

"You are what you eat." When the 19th-century German philosopher Ludwig Feuerbach coined this phrase, he probably did not realize himself how true it was. Foods and people are composed of the same chemical materials, and there was a time when people served as nourishment to other animals in the food chain. All foods, including people, consist of one or more of six basic nutrient groups: water, carbohydrates, lipids, protein, vitamins, and minerals (Figure 3-1). Most foods contain a combination of all six groups, but in varying proportions. For example, milk is 80% water, meats serve as primary sources of protein, potatoes and grains are rich in carbohydrates, and nuts are almost all fat. Figure 3-2 shows the proportion of these six nutrients in humans.

FIGURE 3-1 Nutrient groups



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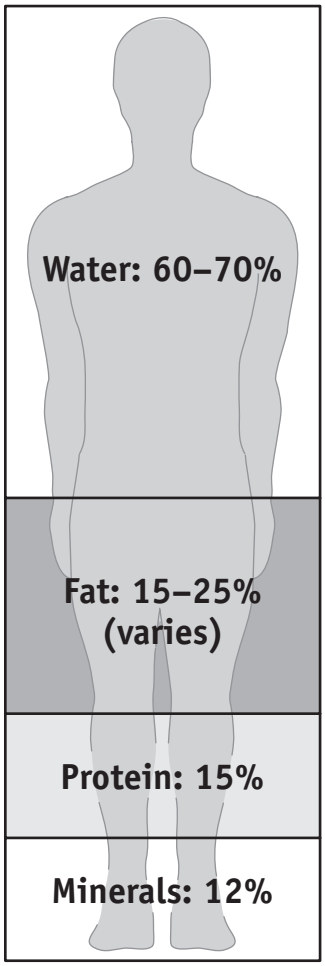
Because people literally are what they eat, the main purpose of eating and drinking is to replace the nutrients used up in the body's maintenance, repair, and growth and to obtain necessary energy. Energy-yielding nutrients are fuel to the body, as gas is fuel to a car.

BASIC FOOD CHEMISTRY: THE SIX KEY ATOMS (CHNOPS)

The body benefits from the energy and nutrients in foods at the cellular level. To comprehend how this occurs, it is necessary to know some biochemistry—the study of the chemistry that occurs within living organisms. Knowledge of biochemistry helps us understand how nutrients from foods and beverages are assimilated in living systems.

FIGURE 3-2 Approximate proportion of nutrients in the human body. Differences occur because of age, sex, and condition. The proportion shown represents percent by weight. Vitamins and carbohydrates contribute a minimal amount.



Atoms The basic building blocks of matter; individual elements found on the periodic table.

Molecule A unit composed of one or more types of atoms held together by chemical bonds.

Compound A substance whose molecules consist of unlike atoms.

Nutrients Food components that nourish the body to provide growth, maintenance, and repair.

Gram A metric unit of weight. One gram (g) is equal to the weight of 1 cubic centimeter (cc) or milliliter (mL) of water (at a specific temperature and pressure).

A basic principle of biochemistry is that all living things contain six key elements (or **atoms**): carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur (CHNOPS) (Chemist's Corner 3-1). These are the building blocks of organic material, carbon-containing compounds that are often living material. All the elements have the capacity to join together with similar or different elements to produce **molecules** or **compounds,** which then combine to create all the substances on earth, including the focus of this book—foods and beverages.

This chapter focuses on both organic and inorganic compounds by covering the six nutrient groups found in food and people: water, carbohydrates, fats, proteins, vitamins, and minerals. These **nutrients** serve as the foundation underlying all the principles in food and nutrition. They are discussed in this chapter with attention to what foods contain them, their chemical composition, and their functions in foods. Sugar (a form of carbohydrate) is discussed in greater detail in Chapter 21, and fat is covered further in Chapter 22.

WATER

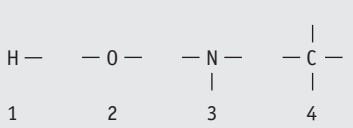
Water is the simplest of all nutrients, yet it is the most important. Without it life could not exist; it is essential at every

CHEMIST'S CORNER 3-1

Atomic Structure

Everything physical in the universe is made from atoms, some of the smallest particles in existence. How are these smallest units of matter identified? The number of protons and electrons that they contain distinguishes them. Protons are positively charged particles in the atom's nucleus, and electrons are negatively charged particles surrounding the nucleus. The number of electrons on the outside ring of an atom dictates how many bonds that particular atom can form, and, therefore, what kind of substances it forms. For example, the carbon (C) atom, the backbone of carbohydrates, fats, and proteins, usually forms four bonds. Nitrogen (N) is capable of forming three bonds, whereas oxygen (O) can form two, and hydrogen (H) only one (Figure 3-3). The bond holding atoms together through the sharing of electrons is called a covalent bond.

FIGURE 3-3 The number of bonds that selected atoms can form with other atoms.



CALORIE CONTROL

Where Do Kilocalories Come From?

Some organic compounds can be broken down by the body to release the energy, measured in kcalories, needed to sustain life. Carbohydrates, fats, proteins, and alcohol are the only sources of kcalories from the diet. No kcalories are obtained from vitamins, minerals, or water. Both water and minerals are inorganic compounds, substances that do not contain carbon and cannot provide kcalories. The following table shows the kcalories provided per **gram.**

Kilocalorie Sources

Yes:		No:
Carbohydrate	= ~4 kcal/gram	Vitamins
Protein	= ~4 kcal/gram	Minerals
Fat	= ~9 kcal/gram	Water
Alcohol	= ~7 kcal/gram	Fiber*

*The carbohydrates in fiber are not digested by human enzymes, so they are not absorbed to provide kcalories.

Conversion factors: 5 grams = 1 teaspoon
28.35 grams = 1 ounce
100 grams = ½ cup liquid

stage of growth and development. Water brings to each living cell the ingredients that it requires and carries away the end products of its life-sustaining reactions. The life functions of assimilating, digesting, absorbing, transporting, metabolizing, and excreting nutrients and their by-products all rely on water. The body's cells are filled with water and are bathed in it. The human body averages 60 to 70% water, and losing as little as 10% can result in death. Water balance is maintained by drinking fluids and by eating foods, all of which naturally contain at least some water. A small portion is also obtained through metabolic processes.

Water Content in Foods

People get the water they need from foods and beverages. Although it may not always be apparent, many foods contain more water than any other nutrient (Chemist's Corner 3-2). Foods have a water content of 0 to 95% or greater (Figure 3-4). Those that yield the most water are fruits and vegetables (70 to 95%), whole milk (over 80%), and most meats (average just under 70%). The foods with the least water are vegetable oils and dried foods such as grains and beans.

Composition of Water

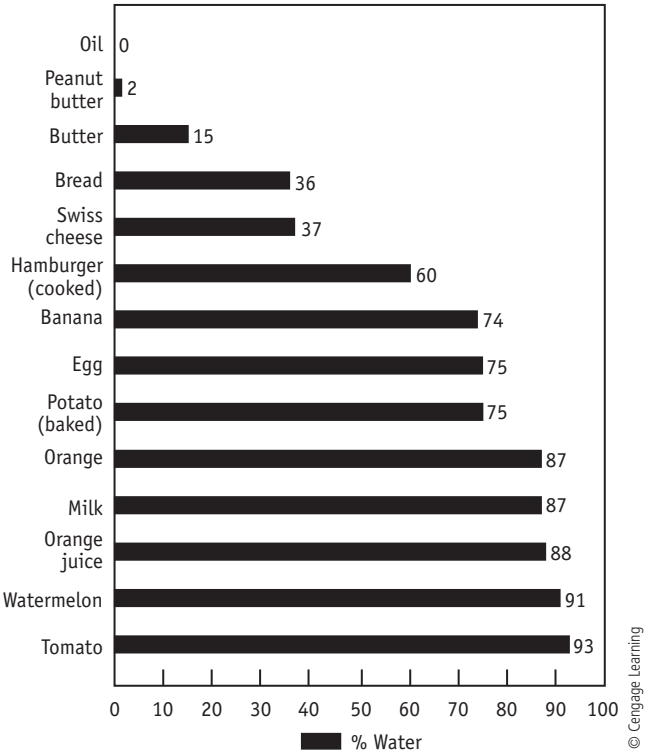
Water is a very small molecule consisting of three atoms—one oxygen atom flanked by two hydrogen atoms (H_2O) (Chemist's Corner 3-3).

CHEMIST'S CORNER 3-2

Free or Bound Water

The water in foods may be in either free or bound form. Free water, the largest amount of water present in foods, is easily separated from the food, whereas bound water is incorporated into the chemical structure of other nutrients such as carbohydrates, fats, and proteins. Examples would be the free water found in fruit and the bound water found in bread. Bound water is not easily removed and is resistant to freezing or drying. It is also not readily available to act as a medium for dissolving salts, acids, or sugars.

FIGURE 3-4 The percent water content of certain foods—0 to 95+.



CHEMIST'S CORNER 3-3

The Chemical Structure and Properties of Water

Water has an overall neutral charge. This "neutrality" is derived from the combination of its two hydrogen (H^+) atoms, each with one positive charge, being balanced by the two negative charges of water's one oxygen (O^{-2}) atom. Overall, this gives water a neutral charge. However, the charge is not evenly distributed over the molecule; the electrons are more strongly attracted by the oxygen atom than by the hydrogen atoms. This results in a water molecule with a negative pole and a positive pole, making it dipolar (Figure 3-5). Dipolar molecules have poles with partial charges that oppose each other, and this dynamic contributes to some of water's very unique properties. Hydrogen bonds form between the (slightly positive) hydrogen atom of one water molecule and the electronegative oxygen atom of an adjacent water molecule. One water molecule is able to form up to four hydrogen bonds. Although these bonds are weak and are easily broken and reformed, they are important because there are so many of them. Energy is required to break them when water is converted to steam. In fact, without hydrogen bonds, water would be a gas at room temperature. In foods, water molecules are able to form hydrogen bonds with other polar molecules such as sugars, starches, gums, and proteins, and this has profound effects on the properties of these molecules in solution.

FIGURE 3-5 Two atoms of hydrogen combine with one oxygen atom, creating a dipolar molecule.