27: Nutrition: Overview and Macronutrients

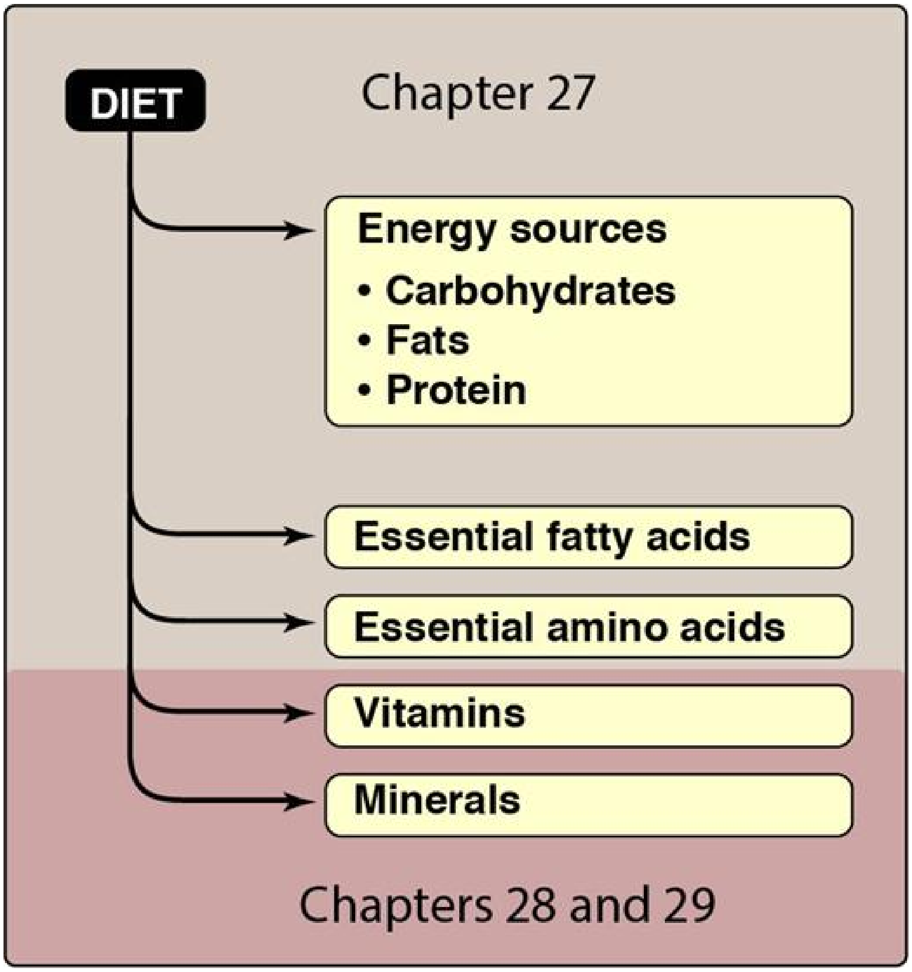
Overview

Nutrients are the constituents of food necessary to sustain the normal functions of the body. All energy (calories) is provided by three classes of nutrients: fats, carbohydrates, and protein (Fig. 27.1). Because the intake of these energy-rich molecules is larger (g amounts) than that of the other dietary nutrients (mg to µg amounts), they are called macronutrients. Although alcohol is also an energy source, it is not a nutrient and it interferes with growth, maintenance, and repair. This chapter focuses on the kinds and amounts of macronutrients that are needed to maintain optimal health and prevent chronic disease. Those nutrients needed in lesser amounts (mg or µg), vitamins and minerals, are called micronutrients and are considered in Chapters 28 and 29. The names macronutrient and micronutrients do not signify their relative importance, but rather denote their relative dietary intake requirements. A nutrient is a micronutrient when less than a gram is required daily.

FIGURE 27.1

Essential nutrients obtained from the diet.

(Note: Ethanol may provide a significant contribution to the daily caloric intake of some individuals.).



Dietary Reference Intakes

Committees of US and Canadian experts organized by the Food and Nutrition Board of the Institute of Medicine of the National Academy of Sciences have compiled Dietary Reference Intakes (DRI), which are estimates of the amounts of nutrients required to prevent deficiencies and maintain optimal health and growth. The DRI expands on the Recommended Dietary Allowances (RDAs), which have been published with periodic revisions since 1941. Unlike the RDA, the DRI establishes upper limits on the consumption of some nutrients and incorporates the role of nutrients in lifelong health, going beyond mere prevention of deficiency diseases. Both the DRI and the RDA refer to long-term average daily nutrient intakes, because it is not necessary to consume the full RDA every day.

Definition

The DRI consists of four dietary reference standards for the intake of nutrients designated for specific life stage (age) groups, physiologic states, and gender (Fig. 27.2).

Estimated average requirement

The average daily nutrient intake level estimated to meet the requirement of 50% of the healthy individuals in a particular life stage and gender group is the Estimated Average Requirement (EAR) (Fig. 27.3). It is useful in estimating the actual requirements in groups and individuals.

FIGURE 27.2

Components of the Dietary Reference Intakes (DRI).

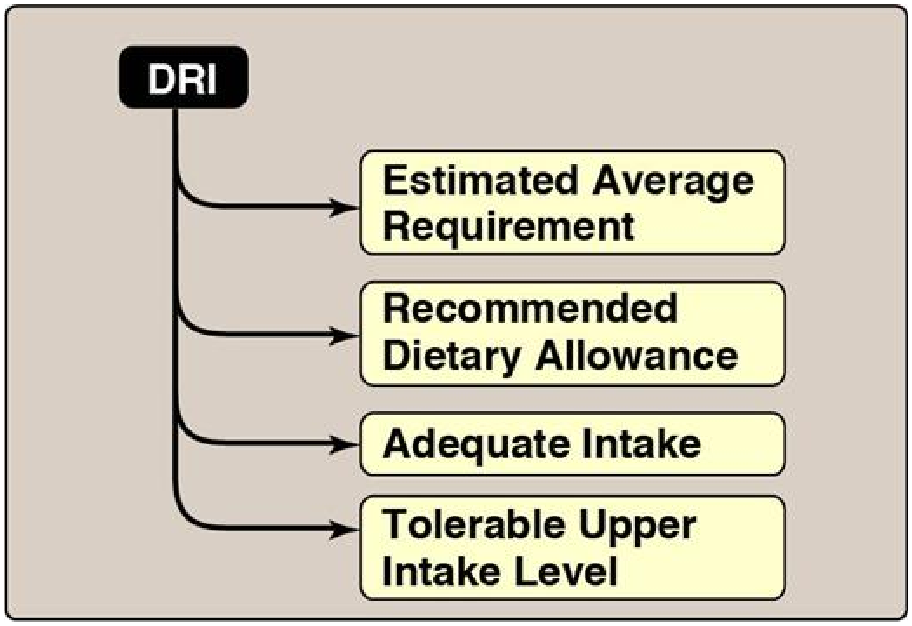
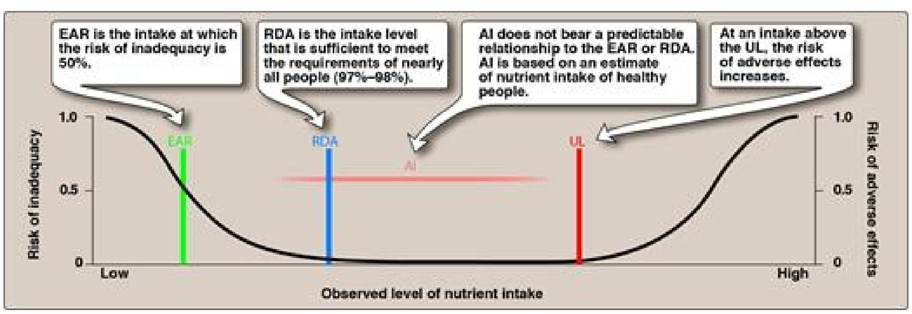


FIGURE 27.3

Comparison of the components of the Dietary Reference Intakes.

EAR = estimated average requirement; RDA = recommended dietary allowance; AI = adequate intake; UL = tolerable upper intake level.



Recommended dietary allowance

The RDA is the average daily nutrient intake level that is sufficient to meet the requirements of nearly all (97% to 98%) individuals in a particular life stage and gender group (Fig. 27.3). The RDA is not the minimal requirement for healthy individuals, but it is intentionally set to provide a margin of safety for most individuals. The EAR serves as the foundation for setting the RDA. If the standard deviation (SD) of the EAR is available and the requirement for the nutrient is normally distributed, the RDA is set at 2 SD above the EAR (i.e., $RDA = EAR + 2\ SD_{EAR}$).

Adequate intake

An Adequate Intake (AI) is set instead of an RDA if sufficient scientific evidence is not available to calculate an EAR or RDA. The AI is based on estimates of nutrient intake by a group (or groups) of apparently healthy people. For example, the AI for young infants, for whom human milk is the recommended sole source of food for the first 6 months, is based on the estimated daily mean nutrient intake supplied by human milk for healthy, full-term infants who are exclusively breast-fed.

Tolerable upper intake level

The highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population is the Tolerable Upper Intake Level (UL). As intake increases above the UL, the potential risk of adverse effects may increase. The UL is useful because of the increased availability of fortified foods and the increased use of dietary supplements. For some nutrients, there may be insufficient data on which to develop a UL.

Using the dietary reference intakes

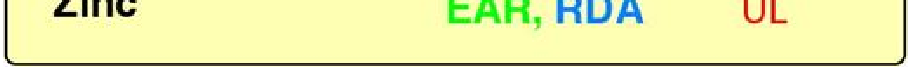
Most nutrients have a set of DRIs (Fig. 27.4). Usually a nutrient has an EAR and a corresponding RDA. Most are set by age and gender and may be influenced by special factors, such as pregnancy and lactation in women (see Section IX). When the data are not sufficient to estimate an EAR (or an RDA), an AI is designated. Intakes below the EAR need to be improved because the probability of adequacy is ≤50% (Fig. 27.3). Intakes between the EAR and RDA likely need to be improved because the probability of adequacy is <98%, and intakes at or above the RDA can be considered adequate. Intakes above the AI can be considered adequate. Intakes between the UL and the RDA can be considered to have no risk for adverse effects. (Note: Because the DRI is designed to meet the nutritional needs of the healthy, it does not include any special needs of the sick.)

FIGURE 27.4

Dietary Reference Intakes for vitamins and minerals in individuals age 1 year and older.

(Note: An RDA has been set for carbohydrate and protein [macronutrients] but not for fat.) EAR = Estimated Average Requirement; RDA = Recommended Dietary Allowance; AI = Adequate Intake; UL = Tolerable Upper Intake Level; — = no value established.

MICRO-NUTRIENT	EAR, RDA, or AI	UL
Thiamine	EAR, RDA	—
Riboflavin	EAR, RDA	—
Niacin	EAR, RDA	UL
Vitamin B_6	EAR, RDA	UL
Folate	EAR, RDA	UL
Vitamin B_{12}	EAR, RDA	—
Pantothenic acid	AI	—
Biotin	AI	—
Choline	AI	UL
Vitamin C	EAR, RDA	UL
Vitamin A	EAR, RDA	UL
Vitamin D	EAR, RDA	UL
Vitamin E	EAR, RDA	UL
Vitamin K	AI	—
Boron	—	UL
Calcium	EAR, RDA	UL
Chromium	AI	—
Copper	EAR, RDA	UL
Fluoride	AI	UL
Iodine	EAR, RDA	UL
Iron	EAR, RDA	UL
Magnesium	EAR, RDA	UL
Manganese	AI	UL
Molybdenum	EAR, RDA	UL
Nickel	—	UL
Phosphorus	EAR, RDA	UL
Selenium	EAR, RDA	UL
Vanadium	—	UL
Zinc	EAR, RDA	UL



Energy Requirement in Humans

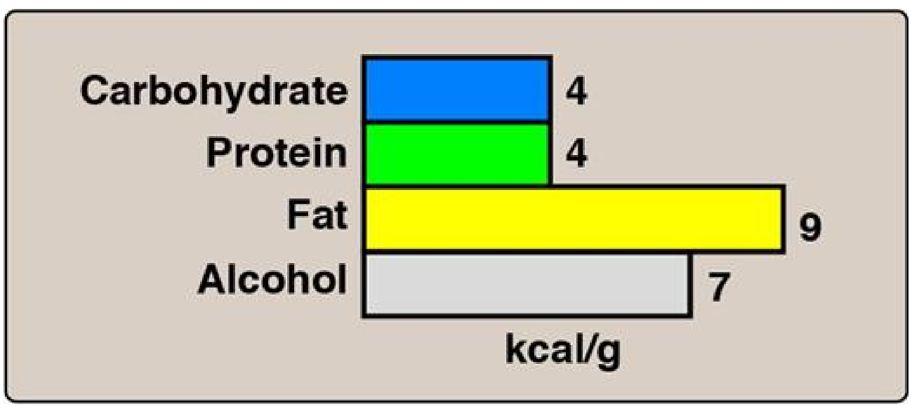
The Estimated Energy Requirement (EER) is the average dietary energy intake predicted to maintain an energy balance (i.e., the calories consumed are equal to the energy expended) in a healthy adult of a defined age, gender, and height whose weight and level of physical activity are consistent with good health. Differences in the genetics, body composition, metabolism, and behavior of individuals make it difficult to accurately predict a person's caloric requirements. However, some simple approximations can provide useful estimates. For example, sedentary adults require approximately 30 kcal/kg/day to maintain body weight, moderately active adults require 35 kcal/kg/day, and very active adults require 40 kcal/kg/day.

Energy content of food

The energy content of food is calculated from the heat released by the total combustion of food in a calorimeter. It is expressed in kilocalories (kcal, or Cal). The standard conversion factors for determining the metabolic caloric value of fat, protein, and carbohydrate are shown in Figure 27.5. A calorie is the amount of energy needed to raise the temperature of 1 gram of water by one-degree Celsius. Kilocalorie is the amount of energy needed to raise 1,000 grams (1 kg) of water by one-degree Celsius. In Nutrition, 1,000-calorie units are known as kilocalories or Cal. That is to say "one gram of carbohydrate is equivalent to 4 calories" in nutrition is actually "one gram of carbohydrate is equivalent to 4000 calories."

FIGURE 27.5

Average energy available from the macronutrients and alcohol.



Note that the energy content of fat is more than twice that of carbohydrate or protein, whereas the energy content of ethanol is intermediate between those of fat and carbohydrate. (Note: The joule [J] is the International System of Units [SI] used for energy and it is widely used in countries other than the United States. One cal = 4.2 J; 1 kcal [1 Cal, 1 food calorie] = 4.2 kJ. For uniformity, many scientists are promoting the use of joules rather than calories in the United States. However, kcal still predominates and is used throughout this text.)

Use of food energy in the body

The energy generated by metabolism of the macronutrients is used for three energy-requiring processes that occur in the body: resting metabolic rate (RMR), physical activity, and the thermic effect of food. Another minor process which requires energy is thermogenesis (not shown in Fig. 27.7). The number of kcal expended by these processes in a 24-hour period is the total energy expenditure (TEE).

Resting metabolic rate

RMR is the energy expended by an individual in a resting, postabsorptive state. It represents the energy required to carry out the normal body functions, such as respiration, blood flow, and ion transport. RMR can be determined by various methods such as calorimetry, doubly labeled water or mathematical formulas. However, indirect calorimetry is the most commonly used method to quantify RMR by measuring oxygen (O_2) consumed or carbon dioxide (CO_2) produced. The ratio of CO_2 to O_2 is the respiratory quotient (RQ). It reflects the metabolic fuel or substrate being oxidized for energy in tissues (Fig. 27.6). RQ for carbohydrates, proteins and fats are 1.0, 0.84, and 0.71 respectively. For example, complete oxidation of glucose uses 6 O_2 and produces 6 CO_2, therefore the ratio is 1. On the other hand, the most common fatty acid, palmitate when oxidized use 23 O_2 and produces 16 CO_2, hence the ratio of RQ = CO_2/O_2 = 0.7. An RQ close to 0.8 reflects the oxidation of the mixture of fat and carbohydrate in the diet.

FIGURE 27.6

The respiratory quotient (RQ).

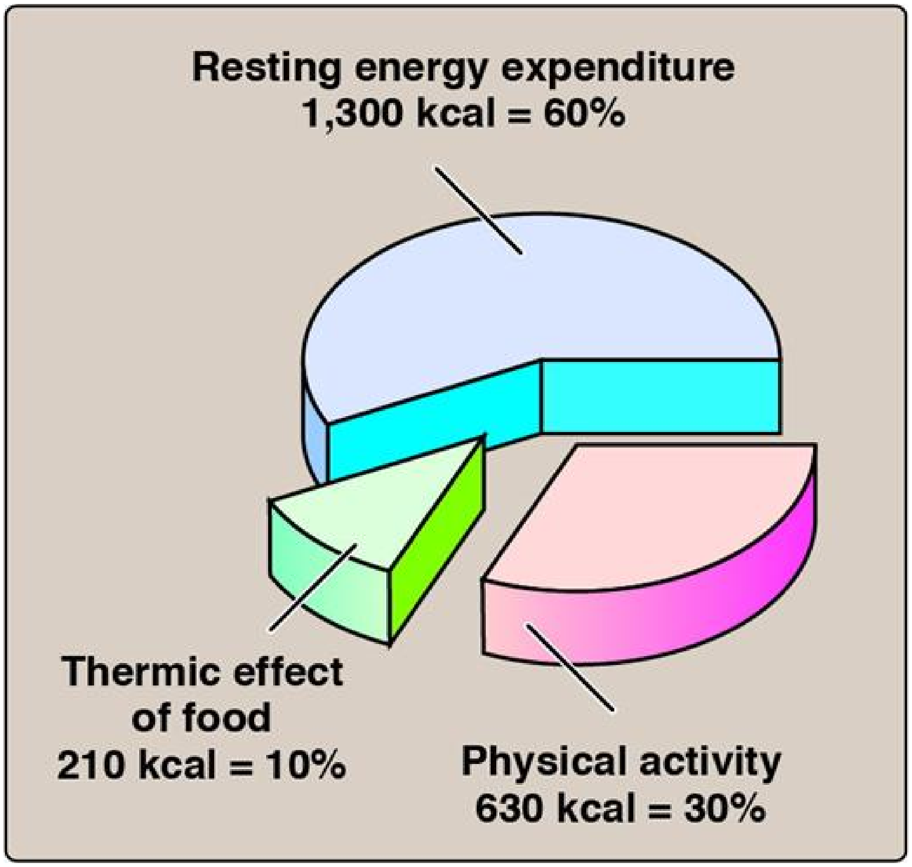
(Note: For protein, the nitrogen is removed and excreted, and the α-keto acids are oxidized.)

SUBSTRATE	RQ
Carbohydrate	1.00
Protein	0.84
Fat	0.71

RMR also can be estimated using equations that include sex and age (RMR reflects lean muscle mass, which is highest in men and the young) as well as height and weight. A commonly used rough estimate is 1 kcal/kg/hr for men and 0.9 kcal/kg/hr for women. (Note: A basal metabolic rate [BMR] can be determined if more stringent environmental conditions are used, but it is not routinely done. RMR is approximately 10% higher than the BMR.) In an adult, the 24-hour RMR, known as the resting energy expenditure (REE), is approximately 1,800 kcal for men (70 kg) and 1,300 kcal for women (50 kg). From 60% to 75% of the TEE in sedentary individuals is attributable to the REE (Fig. 27.7). (Note: Hospitalized individuals are commonly hypercatabolic, and the RMR is multiplied by an injury factor that ranges from 1.0 [mild infection] to 2.0 [severe burns] in calculating their TEE.)

FIGURE 27.7

Estimated total energy expenditure in a healthy 20-year-old woman, 5 ft, 4 in (165 cm) tall, weighing 110 lb (50 kg), and engaged in light activity.



Physical activity

Muscular activity provides the greatest variation in the TEE. The amount of energy consumed depends on the duration and intensity of the exercise. This energy cost is expressed as a multiple of the RMR (range is 1.1 to >8.0) that is referred to as the physical activity ratio (PAR) or the metabolic equivalent of the task (MET). In general, a lightly active person requires approximately 30% to 50% more calories than the RMR (see Fig. 27.7), whereas a highly active individual may require ≥100% calories above the RMR.

Thermic effect of food

The production of heat by the body increases as much as 30% above the resting level during the digestion and absorption of food. This is called the thermic effect of food, or diet-induced thermogenesis. The thermic response to food intake may amount to 5% to 10% of the TEE.

Thermogenesis

There are two types of thermogenesis: adaptive and nonexercise activity thermogenesis (NEAT). Adaptive thermogenesis is the regulated production of heat in response to environmental changes in temperature and diet, for example, shivering in response to cold. NEAT includes the common daily activities, such as fidgeting, walking to work, pacing while talking on the phone and standing.

Acceptable Macronutrient Distribution Ranges

Acceptable Macronutrient Distribution Ranges (AMDRs) are defined as a range of intakes for a particular macronutrient that is associated with reduced risk of chronic disease while providing adequate amounts of essential nutrients. The AMDR for adults is 45% to 65% of their total calories from carbohydrates, 20% to 35% from fat, and 10% to 35% from protein (Fig. 27.8). The biologic properties of dietary fat, carbohydrate, and protein are described below.

FIGURE 27.8

Acceptable Macronutrient Distribution Ranges (AMDR) in adults.

(Note: *A growing body of evidence suggests that higher levels of ω-3 polyunsaturated fatty acids provide protection against coronary heart disease.) RDA = recommended dietary allowance; AI = adequate intake.

MACRONUTRIENT	AMDR (percent of energy)
Fat	20–35
ω–6 Polyunsaturated fatty acids	5–10
ω–3 Polyunsaturated fatty acids	0.6–1.2*
Approximately 10% of the total fat can come from longer-chain, ω–3 or ω–6 fatty acids.	
Carbohydrate	45–65
• RDA Men and women: 130 g/day	
No more than 10% of total calories should come from added sugars.	
Fiber	
• AI Men: 38 g/day; women: 25 g/day	
Protein	10–35
• RDA Men: 56 g/day; women: 46 g/day	

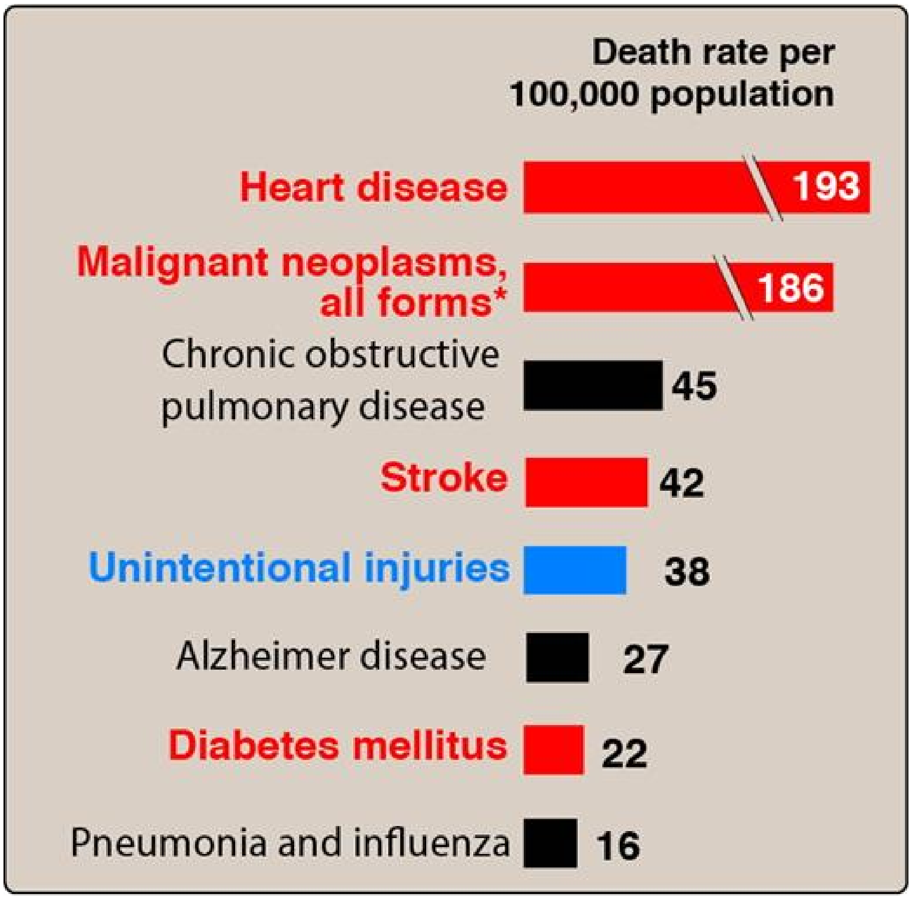
Dietary Fats

The incidence of a number of chronic diseases is significantly influenced by the kinds and amounts of nutrients consumed (Fig. 27.9). Dietary fats most strongly influence the incidence of coronary heart disease (CHD), but evidence linking dietary fat and the risk for cancer or obesity is much weaker.

FIGURE 27.9

Influence of nutrition on some common causes of death in the United States in the year 2010.

Red indicates causes of death in which the diet plays a significant role. Blue indicates causes of death in which excessive alcohol consumption plays a part. (Note: *Diet plays a role in only some forms of cancer.)



> Earlier recommendations emphasized decreasing the total amount of dietary fat. Unfortunately, this resulted in increased consumption of refined grains and added sugars. Data now show that the type of fat is a more important risk factor than the total amount of fat.

Plasma lipids and coronary heart disease

Plasma cholesterol is derived from the diet or from endogenous biosynthesis. In either case, cholesterol is transported between the tissues in combination with protein and phospholipids as lipoproteins.

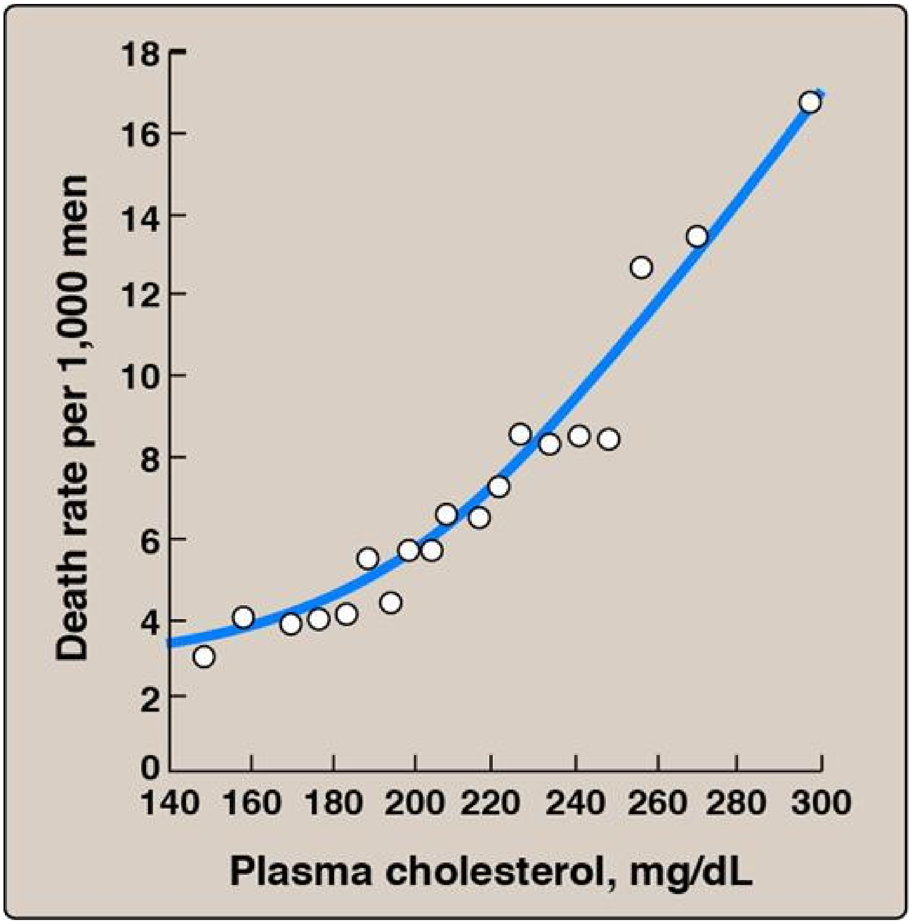
Low-density and high-density lipoproteins

The level of plasma cholesterol is not precisely regulated but, rather, varies in response to diet. Elevated levels of total cholesterol (hypercholesterolemia) result in an increased risk for CHD (Fig. 27.10). A much stronger correlation exists between CHD and the level of cholesterol in low-density lipoproteins ([LDL-C] see Chapter 18). As LDL-C increases, CHD increases. In contrast, elevated levels of high-density lipoprotein cholesterol (HDL-C) have been associated with a decreased risk for heart disease (see Chapter 18). (Note: Elevated plasma triacylglycerol [TAG] is associated with CHD, but a causative relationship has yet to be demonstrated.) Abnormal levels of plasma lipids (dyslipidemias) act in combination with smoking, obesity, sedentary lifestyle, insulin resistance, and other risk factors to increase the risk of CHD.

FIGURE 27.10

Correlation of the death rate from coronary heart disease with the concentration of plasma cholesterol.

(Note: The data were obtained from a multiyear study of men with the death rate adjusted for age.)



Benefits of lowering plasma cholesterol

Dietary or pharmacologic management of hypercholesterolemia has been shown to be effective in decreasing LDL-C, increasing HDL-C, and reducing the risk for cardiovascular events. The diet-induced changes in plasma cholesterol concentrations are modest, typically 10% to 20%, whereas treatment with statin drugs decreases plasma cholesterol by 30% to 60% (see p. 249). (Note: Dietary and drug treatment can also lower TAG.)

Dietary fats and plasma lipids

TAGs are quantitatively the most important class of dietary fats. The influence of TAG on blood lipids is determined by the chemical nature of their constituent fatty acids. The absence or presence and number of double bonds (saturated vs. mono- and polyunsaturated), the location of the double bonds (ω-6 vs. ω-3), and the cis versus trans configuration of the unsaturated fatty acids are the most important structural features that influence blood lipids.

Saturated fats

TAG composed primarily of fatty acids whose hydrocarbon chains do not contain any double bonds are referred to as saturated fats. Consumption of saturated fats is positively associated with high levels of total plasma cholesterol and LDL-C and an increased risk of CHD. The main sources of saturated fatty acids are dairy and meat products and some vegetable oils, such as coconut and palm oils (a major source of fat in Latin America and Asia, although not in the United States). Many experts strongly advise limiting intake of saturated fats to <10% of total caloric intake and replacing them with unsaturated fats (and whole grains).

> Saturated fatty acids with carbon chain lengths of 14 (myristic) and 16 (palmitic) are most potent in increasing the plasma cholesterol level. Stearic acid (18 carbons, found in many foods including chocolate) has little effect on blood cholesterol.

Monounsaturated fats

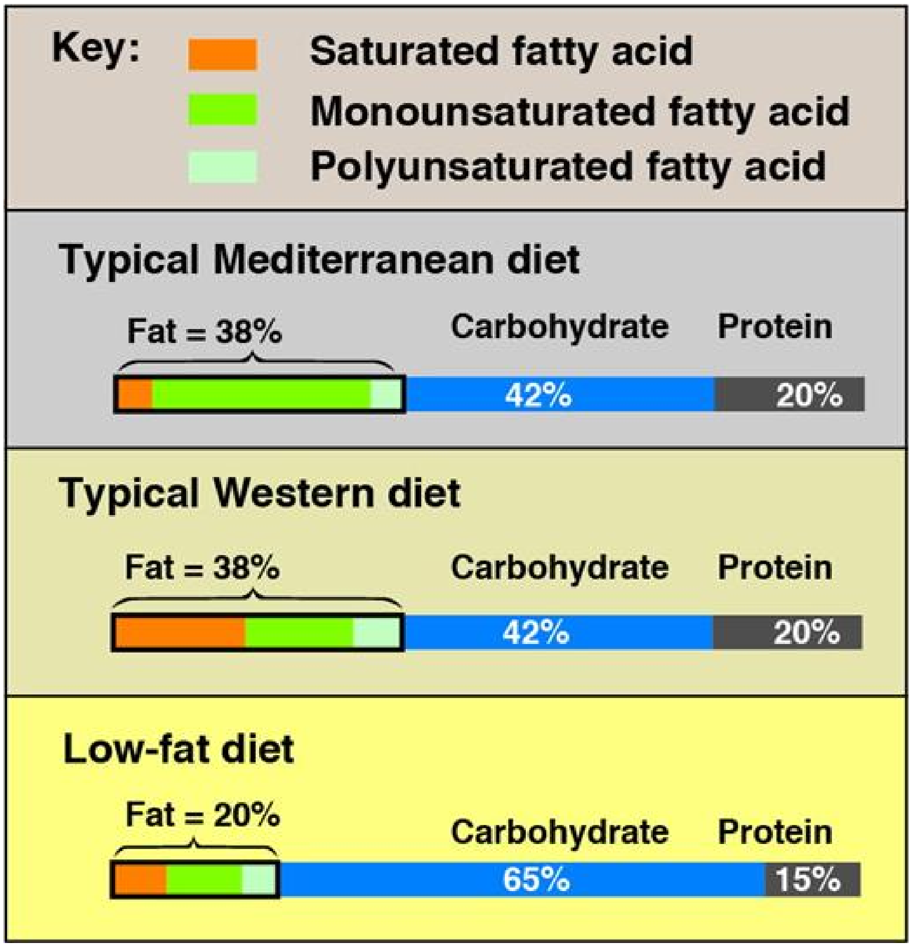
TAGs containing primarily fatty acids with one double bond are referred to as monounsaturated fats (MUFA). Fatty acids containing more than one double bond are termed polyunsaturated fatty acids (PUFA). MUFA are generally obtained from plant-based oils. When substituted for saturated fatty acids in the diet, MUFA lower both total plasma cholesterol and LDL-C and maintain or increase HDL-C. This ability of MUFA to favorably modify lipoprotein levels may explain, in part, the observation that Mediterranean cultures, with diets rich in olive oil (high in monounsaturated oleic acid), show a low incidence of CHD. (Note: Although there is no AMDR for MUFA, it is recommended that the fats in diet should be mostly unsaturated fatty acids [MUFA and PUFA].)

The Mediterranean diet

The Mediterranean diet is an example of a diet rich in MUFA (from olive oil, olives, nuts and fish) and PUFA (from fish oils, plant oils, and some nuts) but low in saturated fat. For example, Figure 27.11 shows the composition of the Mediterranean diet in comparison with both a Western diet similar to that consumed in the United States and a typical low-fat diet. The Mediterranean diet contains seasonally fresh food, with an abundance of plant material, low amounts of red meat, and olive oil as the principal source of fat. The Mediterranean diet is associated with decreased plasma total cholesterol, LDL-C, and TAG, and increased HDL-C when compared with a typical Western diet higher in saturated fats.

FIGURE 27.11

Composition of typical Mediterranean, Western, and low-fat diets.

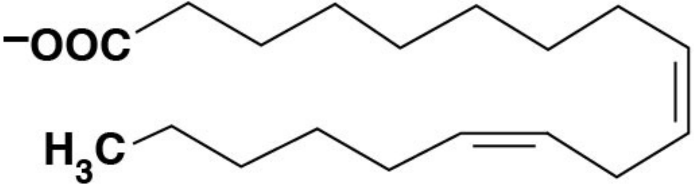


Polyunsaturated fats

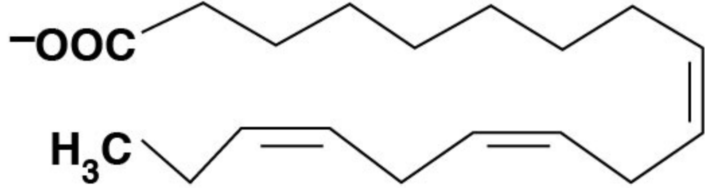
TAGs containing primarily fatty acids with more than one double bond are referred to as polyunsaturated fats. The effects of PUFA on cardiovascular disease are influenced by the location of the double bonds within the molecule.

ω-6 Fatty acids

These are long-chain PUFA, with the first double bond beginning at the sixth bond position when starting from the methyl (ω) end of the fatty acid molecule. (Note: They are also called n-6 fatty acids [see Chapter 16].) Consumption of fats containing ω-6 PUFA, principally linoleic acid (18:2 [9,12]), obtained from vegetable oils, lowers plasma cholesterol when substituted for saturated fats. Plasma LDL-C is lowered, but HDL-C, which protects against CHD, is also lowered, partially offsetting the benefits of lowering LDL-C. Nuts, avocados, olives, soybeans, and various oils, including sunflower and corn oil, are common sources of these fatty acids. The AMDR for linoleic acid is 5% to 10%. (Note: The lower recommendation for intake of PUFA relative to MUFA is because of concern that free radical–mediated oxidation [peroxidation] of PUFA may lead to deleterious products.)



Linoleic acid
(18:2, ω-6)



α-Linolenic acid
(18:3, ω-3)

ω-3 Fatty acids

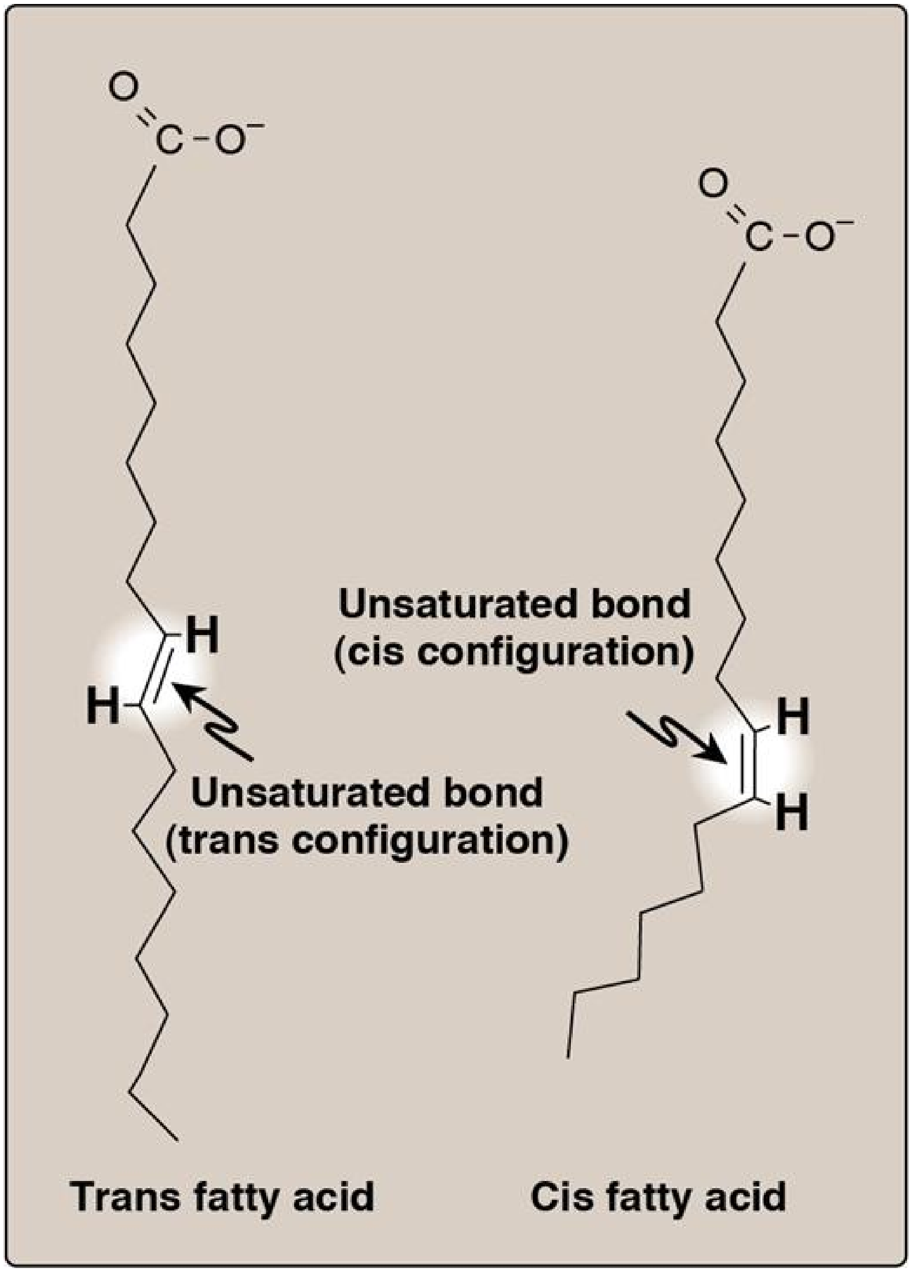
These are long-chain PUFA, with the first double bond beginning at the third bond position from the methyl (ω) end. Dietary ω-3 PUFA suppress cardiac arrhythmias, reduce plasma TAG, decrease the tendency for thrombosis, lower blood pressure, and substantially reduce risk of cardiovascular mortality, but they have little effect on LDL-C or HDL-C levels. Evidence suggests that they have anti-inflammatory effects. The ω-3 PUFA, principally α-linolenic acid, 18:3(9,12,15), are found in plant oils, such as flaxseed and canola, and some nuts, such as walnuts. The AMDR for α-linolenic acid is 0.6% to 1.2%. Fish oil contains the long-chain ω-3 docosahexaenoic acid (DHA, 22:6) and eicosapentaenoic acid (EPA, 20:5). Two meals containing fatty fish (e.g., salmon, mackerel, anchovies, sardines, herring) per week are recommended. (Note: DHA is included in infant formulas to promote brain development.) Linoleic and α-linolenic acids are essential fatty acids (EFAs) required for membrane fluidity and synthesis of eicosanoids (see Chapter 17, VIII). EFA deficiency, caused primarily by fat malabsorption, is characterized by scaly dermatitis as a result of the depletion of skin ceramides with long-chain fatty acids (see Chapter 17, III. F).

Trans fatty acids

Trans fatty acids (Fig. 27.12) are chemically classified as unsaturated fatty acids but behave more like saturated fatty acids in the body because they elevate LDL-C and lower HDL-C, thereby increasing the risk of CHD. Trans fatty acids do not occur naturally in plants but occur in small amounts in animals. However, trans fatty acids are formed during the hydrogenation of vegetable oils (e.g., in the manufacture of margarine and partially hydrogenated vegetable oil). Trans fatty acids are a major component of many commercial baked goods, such as cookies, and most deep-fried foods. Many manufacturers have reformulated their products to be free of trans fats. In 2006, the U.S. Food and Drug Administration required that Nutrition Facts labels (see Section VIII B2) portray the trans-fat content of packaged food and has taken steps to eliminate artificial trans fats in processed foods.

FIGURE 27.12

Structure of cis and trans fatty acids.



Dietary cholesterol

Cholesterol is found only in animal products. The America Heart Association declared in 2015 that “there is insufficient evidence to determine whether lowering dietary cholesterol reduces LDL-C” and the Dietary Guidelines Advisory Committee concluded that the “available evidence shows no appreciable relationship between consumption of dietary cholesterol and serum cholesterol.

Other dietary factors affecting coronary heart disease

Moderate consumption of alcohol (up to 1 drink/day for women and up to 2 drinks/day for men) decreases the risk of CHD, because there is a positive correlation between moderate alcohol (ethanol) consumption and the plasma concentration of HDL-C. However, because of the potential dangers of alcohol abuse, health professionals are reluctant to recommend increased alcohol consumption to their patients. Red wine may provide cardioprotective benefits in addition to those resulting from its alcohol content (e.g., red wine contains phenolic compounds that inhibit lipoprotein oxidation). (Note: These antioxidants are also present in raisins and grape juice.) Figure 27.13 summarizes the effects of dietary fats. (Note: Recent studies [including meta-analyses] have raised questions concerning the current guidelines for dietary fat in the prevention of CHD.)

FIGURE 27.13

Effects of dietary fats.

LDL = low-density lipoprotein; HDL = high-density lipoprotein; DHA = docosahexaenoic acid.

TYPE OF FAT	METABOLIC EFFECTS	EFFECTS ON DISEASE PREVENTION
Trans fatty acid	↑ LDL ↓ HDL	↑ Incidence of coronary heart disease
Saturated fatty acid	↑ LDL Little effect on HDL	↑ Incidence of coronary heart disease; may increase risk of prostate, colon cancer
Monounsaturated fatty acid	↓ LDL Maintain or increase HDL	↓ Incidence of coronary heart disease
Polyunsaturated w−6 fatty acids such as linoleic acid	↓ LDL ↓ HDL Provide arachidonic acid, which is an important precursor of prostaglandins and leukotrienes	↓ Incidence of coronary heart disease
Polyunsaturated w−3 fatty acids such as DHA	Little effect on LDL Little effect on HDL Suppress cardiac arrhythmias, reduce serum triacylglycerols, decrease the tendency for thrombosis, lower blood pressure, reduce inflammation	↓ Incidence of coronary heart disease ↓ Risk of sudden cardiac death

Dietary Carbohydrates

The primary role of dietary carbohydrates is to provide energy. Although self-reported caloric intake in the United States peaked in 2003 and is now declining, the incidence of obesity has dramatically increased (see Chapter 26). During this same period, carbohydrate consumption has significantly increased (as fat consumption decreased), leading some observers to link obesity with carbohydrate consumption. However, obesity has also been related to increasingly inactive lifestyles and to calorie-dense foods served in expanded portion size. Carbohydrates are not inherently fattening.

Classification

Dietary carbohydrates are classified as simple sugars (monosaccharides and disaccharides), complex sugars (polysaccharides), and fiber.

Monosaccharides

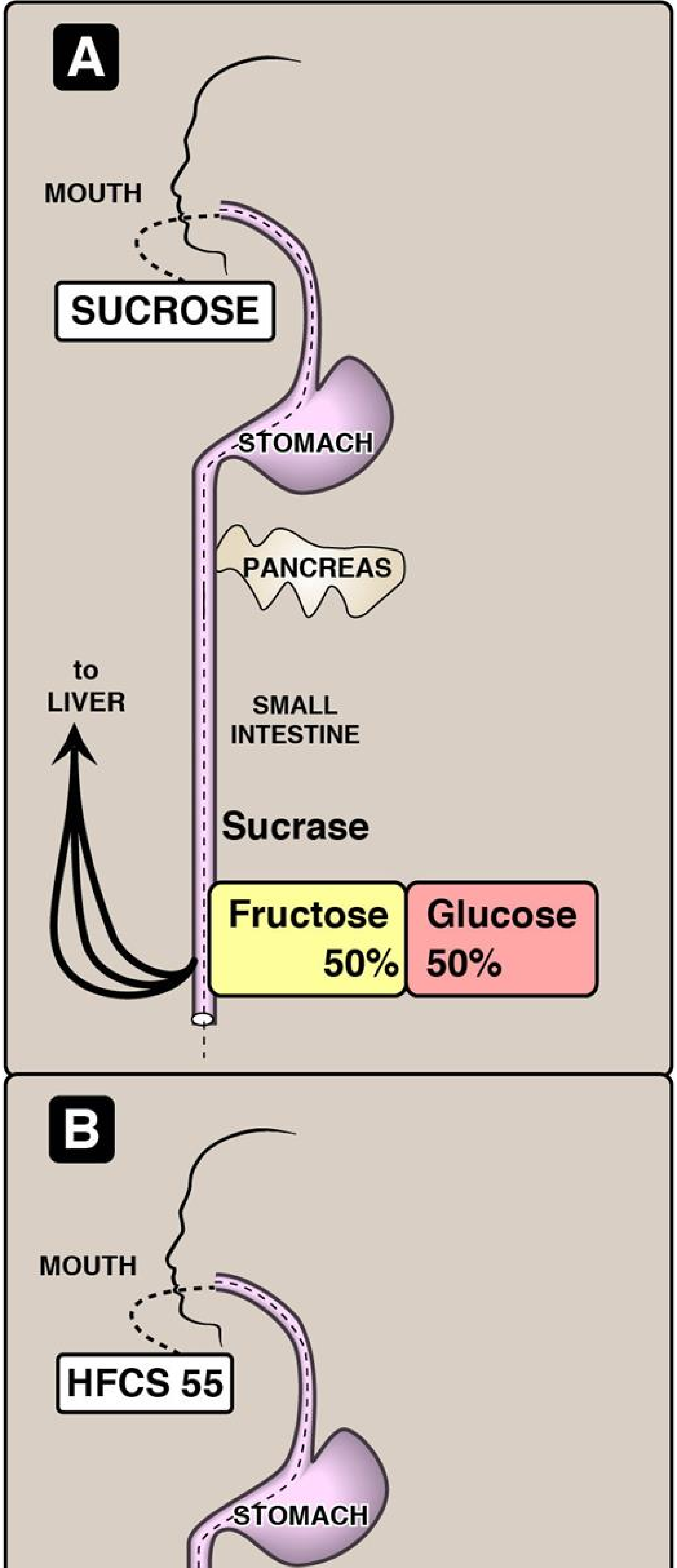
Glucose and fructose are the principal monosaccharides found in food. Glucose is abundant in fruits, sweet corn, corn syrup, and honey. Free fructose is found together with free glucose in honey and fruits (e.g., apples).

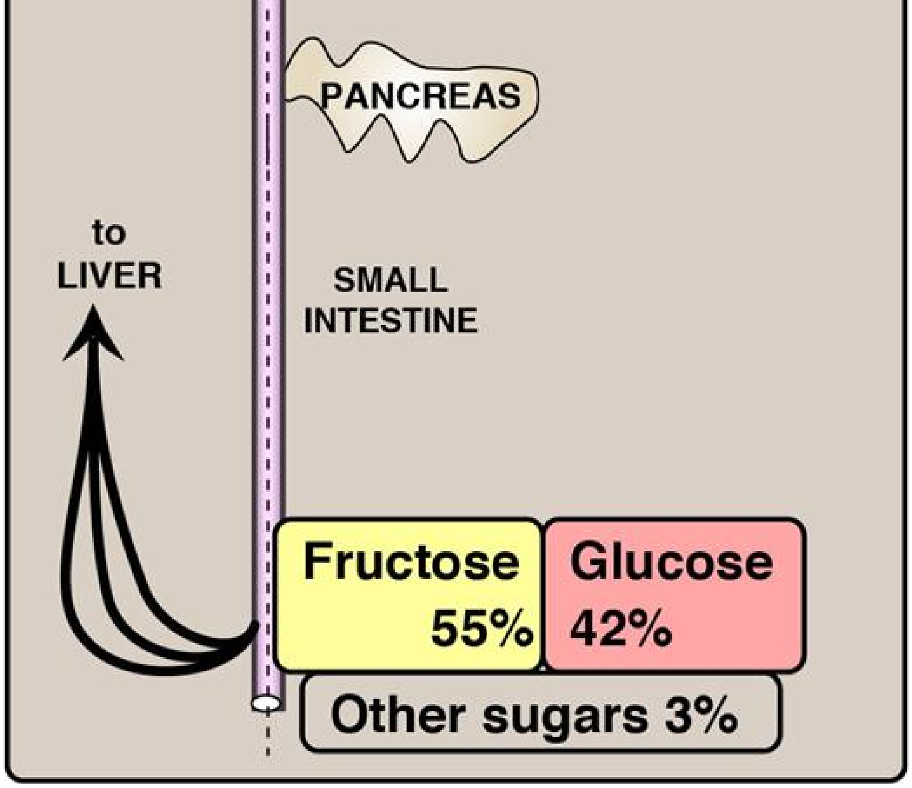
High-fructose corn syrup

High-fructose corn syrups (HFCSs) are prepared through enzymatic processing to convert glucose into fructose. Pure corn syrup (100% glucose) is then added to fructose to produce a desired sweetness. In the United States, HFCS 55 (containing 55% fructose and 42% glucose) is commonly used as a substitute for sucrose in beverages, including soft drinks, with HFCS 42 used in processed foods. The composition and metabolism of HFCS and sucrose are similar, the major difference being that HFCS is ingested as a mixture of monosaccharides (Fig. 27.14). Most studies have shown no significant difference between sucrose and HFCS meals in either postprandial glucose or insulin responses. (Note: The rise in the use of HFCS parallels the rise in obesity, but a causal relationship has not been demonstrated.)

FIGURE 27.14

Digestion of sucrose, (A), or high-fructose corn syrup (HFCS) 55, (B), leads to absorption of glucose plus fructose.


A
MOUTH
SUCROSE
STOMACH
PANCREAS
to
LIVER
SMALL
INTESTINE
Sucrase
Fructose
50%
Glucose
50%
B
MOUTH
HFCS 55
STOMACH



Disaccharides

The most abundant disaccharides are sucrose (glucose + fructose), lactose (glucose + galactose), and maltose (glucose + glucose). Sucrose is ordinary table sugar and is abundant in molasses and maple syrup. Lactose is the principal sugar found in milk. Maltose is a product of enzymic digestion of glycogen and starches in the intestine. It is also found in significant quantities in beer and malt liquors as maltose is found in germinating grains. The term “sugar” refers to monosaccharides and disaccharides. “Added sugars” are those sugars and syrups (such as HFCS) added to foods during processing or preparation.

Polysaccharides

Complex carbohydrates are composed of oligosaccharides and polysaccharides which are predominantly polymers of glucose. Examples of polysaccharides are starch, glycogen, and dietary fiber. Starch is an example of a complex carbohydrate that is found in abundance in plants. Common sources include wheat and other grains, potatoes, dried peas and beans (legumes), and vegetables.

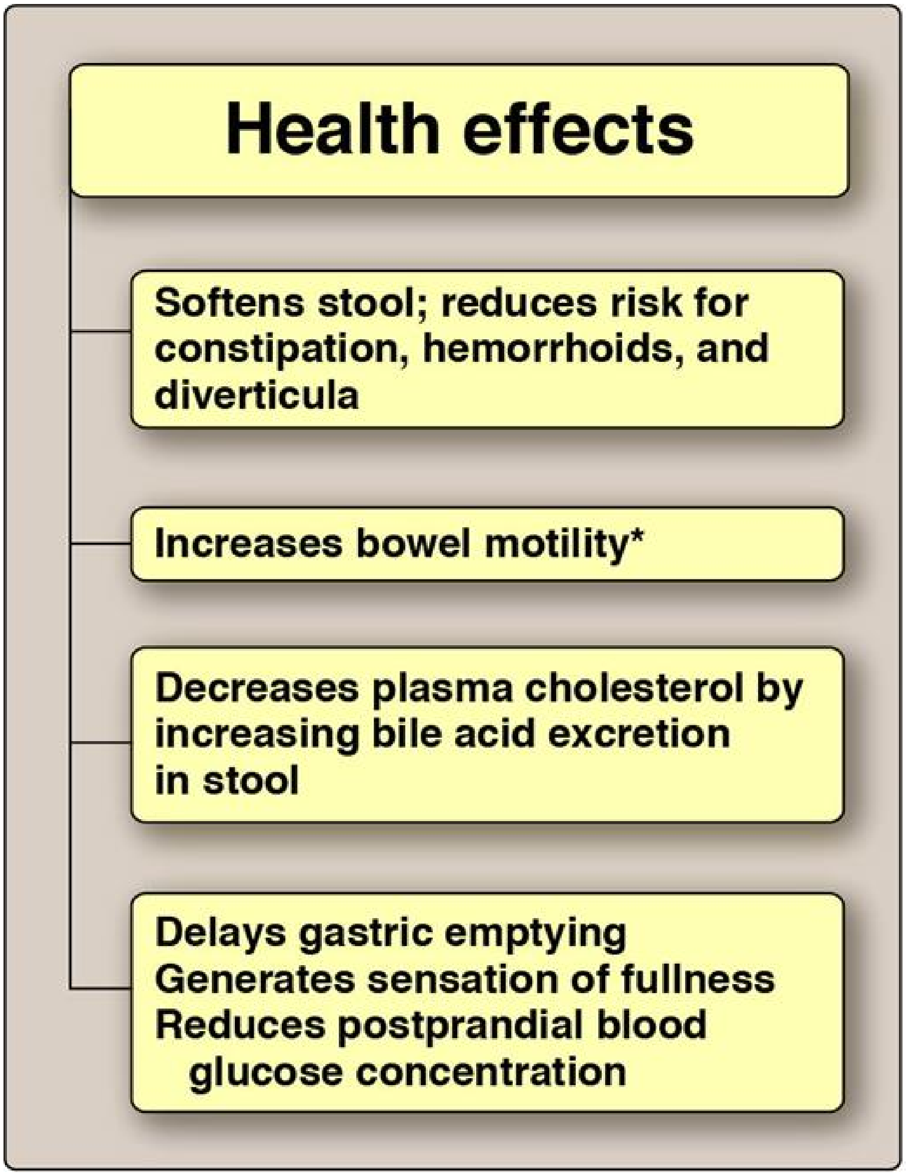
Fiber

Dietary fiber is the edible part of plants which is nondigestible, nonstarch carbohydrates and lignin (a noncarbohydrate polymer of aromatic alcohols). Although soluble fiber is resistant to digestion and absorption in the human small intestine, it is completely or partially fermented by the gut bacteria to short-chain fatty acids (SCFA) in the large intestine. SCFAs play an essential role in regulating host metabolism, immune system, and cell proliferation. Insoluble fiber passes through the digestive track largely unchanged. Dietary fiber provides little energy but has several beneficial effects. First, it adds bulk to the diet (Fig. 27.15). Fiber can absorb 10 to 15 times its own weight in water, drawing fluid into the lumen of the intestine and increasing bowel motility and promoting bowel movements (laxation). Soluble fiber delays gastric emptying and can result in a sensation of fullness (satiety). This delayed emptying also results in reduced spikes in blood glucose following a meal. Second, consumption of soluble fiber has been shown to lower LDL-C levels by increasing fecal bile acid excretion and interfering with bile acid reabsorption (see Chapter 18 Section V). For example, diets rich (25 to 50 g/day) in the soluble fiber oat bran are associated with a modest, but significant, reduction in risk for CHD by lowering total cholesterol and LDL-C levels. Also, fiber-rich diets decrease the risk for constipation, hemorrhoids, and diverticulosis. The AI for dietary fiber is 25 g/day for women and 38 g/day for men. However, most American diets are far lower in fiber at approximately 15 g/day. (Note: “Functional fiber” is the term used for isolated fiber that has proven health benefits such as commercially available fiber supplements.) Introduction of fiber into the diet should be gradual as it can lead to abdominal discomfort, gas, diarrhea, and even constipation.

FIGURE 27.15

Actions of dietary fiber.

(Note: *Increasing bowel motility decreases exposure time of the intestines to carcinogens.)



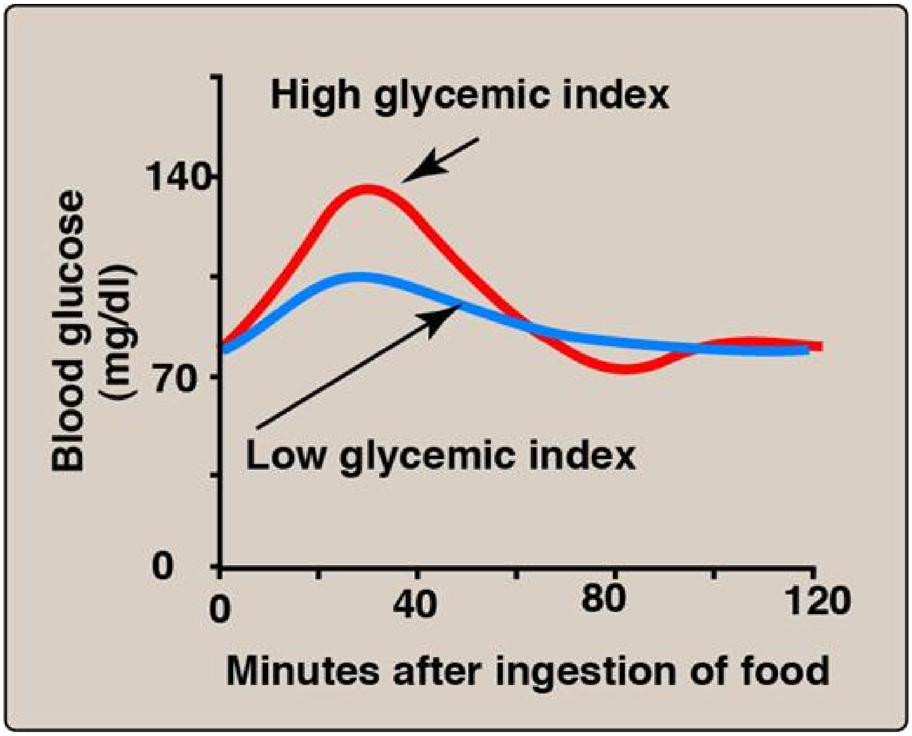
Dietary carbohydrate and blood glucose

Some carbohydrate-containing foods produce a rapid rise followed by a steep fall in blood glucose concentration, whereas others result in a gradual rise followed by a slow decline (Fig. 27.16). Thus, they differ in their glycemic response (GR). (Note: Fiber blunts the GR.) The glycemic index (GI) ranks carbohydrate-rich foods on a scale of 0 to 100 based on the GR they cause relative to the GR caused by the same amount (50 g) of carbohydrate eaten in the form of white bread or glucose. A low GI is <55, whereas a high GI is ≥70. Evidence suggests that a low-GI diet improves glycemic control in diabetic individuals. Food with a low GI tends to create a sense of satiety over a longer period of time and may be helpful in limiting caloric intake. (Note: How much a typical serving size of a food raises blood glucose is referred to as the glycemic load (GL). A food (e.g., carrots) can have a high GI and a low GL.)

FIGURE 27.16

Blood glucose concentrations following ingestion of food with a low or high glycemic index (GI).

(Note: The GI is defined as the area under the blood glucose curve.)



Carbohydrate requirements

Carbohydrates are not essential nutrients, because the carbon skeletons of most amino acids can be converted into glucose (see Chapter 20 Section II A). However, they supply essential nutrients such as vitamins and minerals. In addition, the absence of dietary carbohydrate leads to ketogenesis (see Chapter 16 Section V) and degradation of body protein whose constituent amino acids provide carbon skeletons for gluconeogenesis (see Chapter 10 Section II C). The RDA for carbohydrate is set at 130 g/day for adults and children, based on the amount of glucose used by carbohydrate-dependent tissues, such as the brain and erythrocytes. However, this level of intake is usually exceeded. Adults should consume 45% to 65% of their total calories from carbohydrates. It is now recommended that added sugars represent no more than 10% of total energy intake because of concerns that they may displace nutrient-rich foods from the diet. (Note: Added sugars are associated with increased body weight and type 2 diabetes.)

Simple sugars and disease

There is no direct evidence that the consumption of simple sugars naturally present in food is harmful. Contrary to folklore, diets high in sucrose do not lead to diabetes or hypoglycemia. Also contrary to popular belief, carbohydrates are not inherently fattening. They yield 4 kcal/g (the same as protein and less than one half that of fat; see Fig. 27.5) and result in fat synthesis only when consumed in excess of the body's energy needs. However, there is an association between sucrose consumption and dental caries, particularly in the absence of fluoride treatment (see Chapter 29 Section III E).

Dietary Protein

The AMDR for protein is 10% to 35%. Dietary protein provides the essential amino acids (EAAs) (see Fig. 20.2). Nine of the 20 amino acids needed for the synthesis of body proteins are essential (i.e., they cannot be synthesized in humans).

Protein quality

The quality of a dietary protein is a measure of its ability to provide the EAAs required for tissue maintenance. Most government agencies have adopted the Protein Digestibility–Corrected Amino Acid Score (PDCAAS) as the standard by which to evaluate protein quality. PDCAAS is based on the profile of EAA after correcting for the digestibility of the protein. The highest possible score under these guidelines is 1.00. This amino acid score provides a method to balance intakes of poorer-quality proteins with high-quality dietary proteins.

Proteins from animal sources

Proteins from animal sources (meat, poultry, milk, and fish) have a high quality because they contain all the EAAs in proportions similar to those required for synthesis of human tissue proteins (Fig. 27.17), and they are more readily digested. (Note: Gelatin prepared from animal collagen is an exception. It has a low biologic value as a result of deficiencies in several EAA.)

FIGURE 27.17

Relative quality of some common dietary proteins.

PDCAAS = Protein Digestibility–Corrected Amino Acid Score.

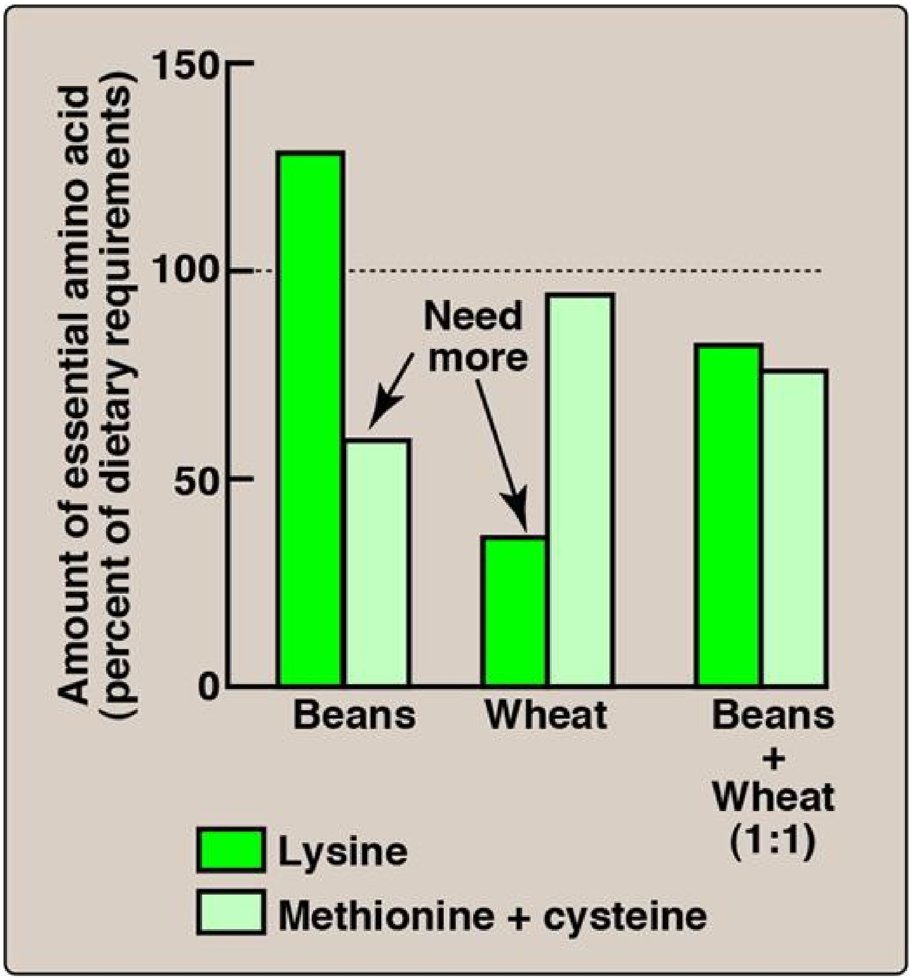
Source	PDCAAS value
Animal proteins	
Egg	1.00
Milk protein	1.00
Beef/poultry/fish	0.82–0.92
Gelatin	0.08
Plant proteins	
Soybean protein	1.00
Kidney beans	0.68
Whole wheat bread	0.40

Proteins from plant sources

Plant proteins have a lower quality than do animal proteins since they have low amounts of more than one of the EAAs. Therefore, they are called incomplete proteins. Animal proteins such as egg, milk and meat are known as complete proteins because they contain adequate levels of all EAAs. Proteins from different plant sources may be combined in such a way that the result is equivalent in nutritional value to animal protein. For example, wheat (lysine deficient but methionine rich) may be combined with kidney beans (methionine poor but lysine rich) to produce a higher biologic value than either of the component proteins (Fig. 27.18). (Note: Animal proteins can also complement the biologic value of plant proteins.)

FIGURE 27.18

Combining two incomplete proteins that have complementary amino acid deficiencies results in a mixture with a higher biologic value.



Nitrogen balance

Nitrogen balance occurs when the amount of nitrogen consumed equals that of the nitrogen excreted in the urine (primarily as urinary urea nitrogen, or UUN), sweat, and feces. Most healthy adults are normally in nitrogen balance. (Note: There is, on average, 1 g nitrogen in 6.25 g protein.)

Positive nitrogen balance

This occurs when nitrogen intake exceeds nitrogen excretion. It is observed during situations in which tissue growth occurs, for example, in childhood, pregnancy, or during recovery from an emaciating illness.

Negative nitrogen balance

This occurs when nitrogen loss is greater than nitrogen intake. It is associated with inadequate dietary protein; lack of an EAA; or during physiologic stresses, such as trauma, burns, illness, or surgery.

> Nitrogen (N) balance (g N_{in} – g N_{out}) in a 24-hour period can be determined by the formula, N balance = protein intake in g/6.25 – (UUN + 4 g), where 4 g accounts for urinary loss in forms other than UUN plus loss in skin and feces.

Protein requirements

The amount of dietary protein required in the diet varies with its biologic value. The greater the proportion of animal protein in the diet, the less protein is required. The RDA for protein is computed for proteins of mixed biologic value at 0.8 g/kg of body weight for adults, or approximately 56 g of protein for a 70-kg individual. People who exercise strenuously on a regular basis may benefit from extra protein to maintain muscle mass, and a daily intake of approximately 1 g/kg has been recommended for athletes. Women who are pregnant or lactating require up to 30 g/day in addition to their basal requirements. To support growth, infants should consume 2 g/kg/day. (Note: Disease states influence protein needs. Protein restriction may be needed in kidney disease, whereas burns require increased protein intake.)

Consumption of excess protein

There is no physiologic advantage to the consumption of more protein than the RDA. Protein consumed in excess of the body's needs is deaminated, and the resulting carbon skeletons are metabolized to provide energy or acetyl coenzyme A for fatty acid synthesis. When excess protein is eliminated from the body as urinary nitrogen, it is often accompanied by increased urinary calcium, thereby increasing the risk of nephrolithiasis (kidney stones) and osteoporosis.

The protein-sparing effect of carbohydrates

The dietary protein requirement is influenced by the carbohydrate content of the diet. When the intake of carbohydrates is low, amino acids are deaminated to provide carbon skeletons for the synthesis of glucose that is needed as a fuel by the central nervous system. If carbohydrate intake is <130 g/day, substantial amounts of protein are metabolized to provide precursors for gluconeogenesis. Therefore, carbohydrate is considered to be "protein-sparing," because it allows amino acids to be used for repair and maintenance of tissue protein rather than for gluconeogenesis.

Protein-energy (calorie) malnutrition

In developed countries, protein-energy malnutrition (PEM), also known as protein-energy undernutrition (PEU), is most commonly seen in patients with medical conditions that decrease appetite or alter how nutrients are digested or absorbed or in hospitalized patients with major trauma or infections. (Note: Such highly catabolic patients frequently require intravenous [IV, or parenteral] or tube-based [enteral] administration of nutrients.) PEM may also be seen in children or the elderly who are malnourished. In developing countries, an inadequate intake of protein and/or calories is the primary cause of PEM. Affected individuals show a variety of symptoms, including a depressed immune system with a reduced ability to resist infection. Death from secondary infection is common. PEM is a spectrum of degrees of malnutrition, and two extreme forms are kwashiorkor and marasmus (Table 27.1). (Note: Marasmic kwashiorkor has features of both forms.)

Kwashiorkor

Kwashiorkor occurs when protein deprivation is relatively greater than the reduction in total calories. Protein deprivation is associated with severely decreased synthesis of visceral protein. Kwashiorkor is commonly seen in developing countries in children after weaning at about age 1 year, when their diet consists predominantly of carbohydrates. Typical symptoms include stunted growth, skin lesions, depigmented hair, anorexia, fatty liver, bilateral pitting edema, and decreased serum albumin concentration. Edema results from the lack of adequate blood proteins, primarily albumin, to maintain the distribution of water between blood and tissues. It may mask muscle and fat loss. Therefore, chronic malnutrition is reflected in the level of serum albumin. (Note: Because caloric intake from carbohydrates may be adequate, insulin levels suppress lipolysis and proteolysis. Kwashiorkor is, therefore, nonadapted malnutrition.)

TABLE 27.1

Physical Features of Extreme Protein-Energy Malnutrition (PEM) in Children

Type of PEM	Weight for Age (% Expected)	Weight for Height	Edema	Muscle and Fat Content
Kwashiorkor	60–80	Normal or ↓	Present	↓
Marasmus	<60	Markedly ↓	Absent	Markedly ↓

Note: The fatty liver and skin and hair changes of kwashiorkor are not seen in marasmus.

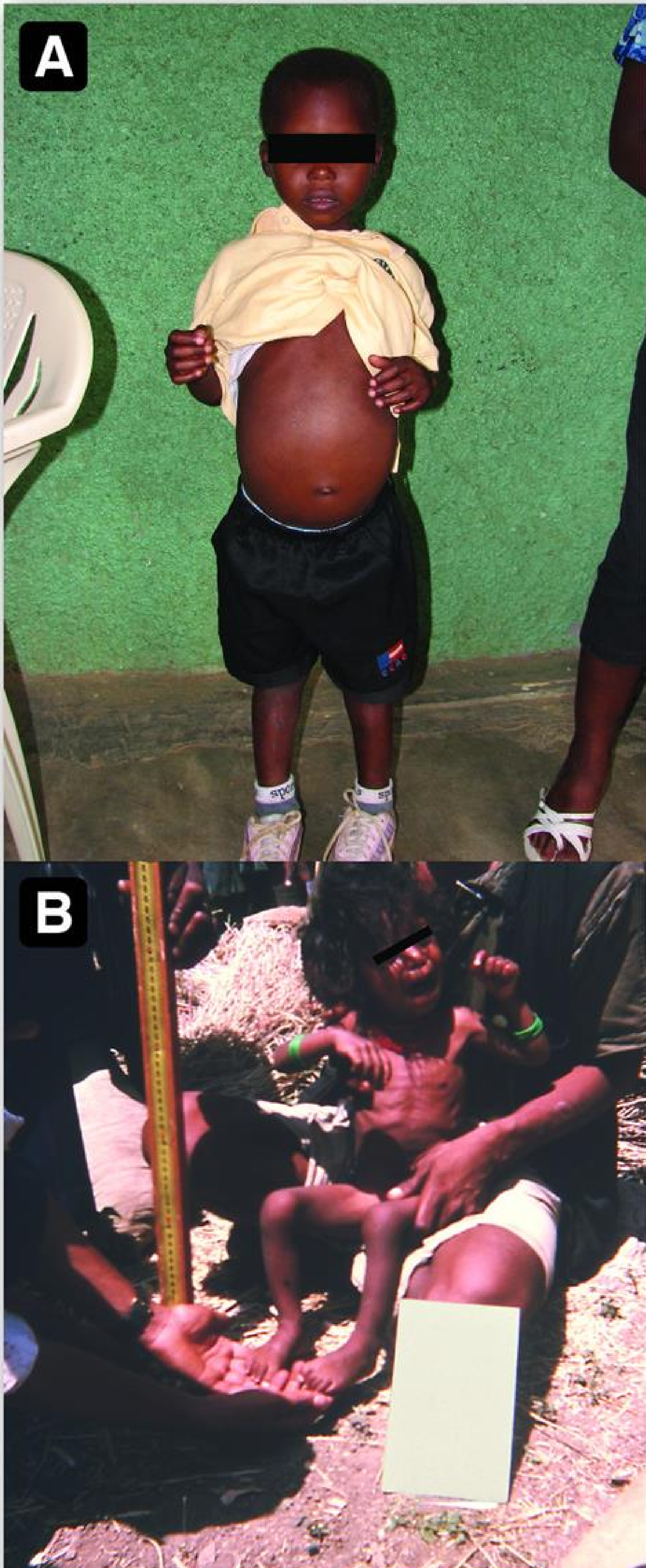
Marasmus

Marasmus occurs when calorie deprivation is relatively greater than the reduction in protein. It usually occurs in developing countries in children younger than age 1 year when breast milk is supplemented or replaced with watery gruels of native cereals that are usually deficient in both protein and calories. Typical symptoms include arrested growth, extreme muscle wasting and depletion of subcutaneous fat (emaciation), weakness, and anemia (Fig. 27.19). Individuals with marasmus do not show the edema observed in kwashiorkor. (Note: Refeeding severely malnourished individuals can result in hypophosphatemia (see Chapter 29 Section II A2), because any available phosphate is used to phosphorylate carbohydrate intermediates. Milk is frequently given because it is rich in phosphate.)

FIGURE 27.19

A: A child with kwashiorkor. Note the swollen belly and lower legs. **B:** Child suffering with marasmus.

A, Corey Heitz, MD. https://www.flickr.com/photos/coreyheitzmd/3478702894. B, Centers for Disease Control and Prevention Public Health Image Library. Atlanta, GA.


A
B

Cachexia, a wasting disorder characterized by loss of appetite and muscle atrophy (with or without increased lipolysis) that cannot be reversed by conventional nutritional support, is seen with a number of chronic diseases, such as cancer and chronic pulmonary and renal disease. It is associated with decreased treatment tolerance and response and decreased survival time.

Nutrition Tools

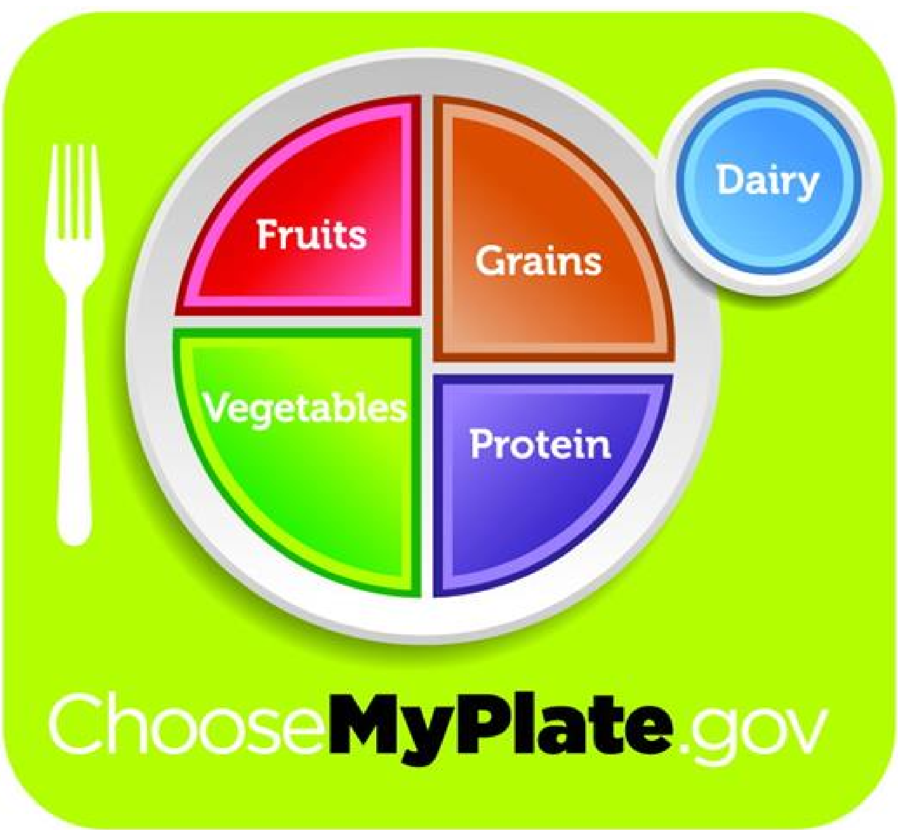
A set of tools has been developed that gives consumers information about what (and how much) they should eat as well as the nutritional content of the foods they do eat. Additional tools allow medical professionals to assess whether or not the nutritional needs of an individual are being met.

MyPlate

MyPlate was designed by the U.S. Department of Agriculture (USDA) to graphically illustrate its recommendations as to what food groups and how much of each should be consumed daily. In MyPlate, the relative amounts of each of five food groups (vegetables, grains, protein, fruit, and dairy) are represented by the relative size of their section on the plate (Fig. 27.20). The number of servings depends on variables that include age and sex. The Healthy Eating Plate created by experts at Harvard School of Public Health and Harvard Medical School is also used. It differs from MyPlate which recommends limiting milk and substituting with water. In addition, it recommends healthy oils and physical activity.

FIGURE 27.20

MyPlate.



Nutrition facts label

Most types of packaged goods are required to have a Nutrition Facts label, or "food label" (Fig. 27.21), that includes the size of a single serving, the Cal it provides, and the number of servings per container. In addition, a percent daily value (%DV) is shown for most nutrients listed. (Note: The %DV is based on a 2,000-Cal diet for healthy adults.)

Percent daily value

The %DV compares the amount of a given nutrient in a single serving of a product to the recommended daily intake for that nutrient. For example, the %DV for the micronutrients listed, as well as for total carbohydrates and fiber, are based on their recommended minimum daily intake. Thus, if the label lists 20% for calcium, one serving provides 20% of the minimum recommended amount of calcium needed each day. In contrast, the %DV for saturated fat, cholesterol, and sodium are based on their recommended maximum daily intake, and the %DV reflects what percentage of this maximum a serving provides. There is no %DV for protein because the recommended intake depends on body weight. (Note: "Sugars" represents mono- and disaccharides. The remainder of the carbohydrate [total carbohydrate – (fiber + sugars)] is the oligo- and polysaccharides.)

FIGURE 27.21

Nutrition Facts label (food label).

Nutrition Facts

Serving Size 1 cup (228 g)
Servings Per Container about 2

Amount Per Serving

Calories 250	Calories from Fat 110
	% Daily Value*
Total Fat 12 g	**18%**
Saturated Fat 3 g	**15%**
Trans Fat 3 g	
Cholesterol 30 mg	**10%**
Sodium 470 mg	**20%**
Total Carbohydrate 31 g	**10%**
Dietary Fiber 0 g	**0%**
Sugars 5 g	
Proteins 5 g	
Vitamin A	4%
Vitamin C	2%
Calcium	20%
Iron	4%

* Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65 g	80 g
Saturated Fat	Less than	20 g	25 g
Cholesterol	Less than	300 mg	300 mg
Sodium	Less than	2,400 mg	2,400 mg
Total Carbohydrate		300 g	375 g
Dietary Fiber		25 g	30 g

Nutrition Facts labels

In 2014, the USDA proposed the following changes to the Nutrition Facts label: Added sugars, vitamin D, and potassium are to be included; vitamins A and C, total fat, and Cal from fat are to be removed since the type of fat is more important than the amount; and serving size is to be adjusted to reflect the amounts people are now consuming. Additionally, design was changed to highlight key parts of the label (Fig. 27.22).

FIGURE 27.22

Nutrition Facts label showing changes proposed in 2014 for implementation by 2018.

Nutrition Facts

8 servings per container

Serving size 2/3 cup (55 g)

Amount per 2/3 cup

Calories 230

% DV*	
12%	**Total Fat** 8 g
5%	**Saturated Fat** 1 g
	Trans **Fat** 0 g
0%	**Cholesterol** 0 mg
7%	**Sodium** 160 mg
12%	**Total Carbs** 37 g
14%	**Dietary Fiber** 4 g
	Sugars 1 g
	Added Sugars 0 g
	Protein 3 g
10%	**Vitamin D** 2 mcg
20%	**Calcium** 260 mg
45%	**Iron** 8 mg
5%	**Potassium** 235 mg

* Footnote on Daily Values (DV) and calories reference to be inserted here.

Nutrition assessment

Nutrition assessment evaluates nutritional status based on clinical information. It includes (but is not limited to) dietary history, anthropometric measures, and laboratory data. Assessment findings may result in medical nutrition therapy (MNT), which is an evidence-based medical approach for the treatment of certain medical conditions using a personalized nutrition plan. For example, MNT for hyperlipidemia involves reducing the quantity and types of fats and often calories in the diet.

Dietary history

This is a record of food intake over a period of time. For a food diary, the specific types and exact amounts of food eaten are recorded in "real time" (as soon as possible after eating) for a period of 3 to 7 days. Retrospective approaches include a food frequency questionnaire (e.g., what fruits were eaten and how often they were eaten in a typical day, week, or month) and a 24-hour recall of the specific foods and the amounts eaten in the last 24 hours.

Anthropometric measures

These are physical measures of the body. They include (but are not limited to) weight, height, body mass index (an indicator of obesity, see Chapter 26 II A), skin-fold thickness (an indicator of subcutaneous fat), and waist circumference (an indicator of abdominal fat, see Chapter 26 II). (Note: Ideal body weight can be calculated using the Hamwi method: 106 lb [for males] or 100 lb [for females] for the first 5 ft of height + 5 lb for every inch over 5 ft, with an adjustment of −10% for a small frame and +10% for a large one.)

Laboratory data

These are obtained by tests performed on body fluids, tissues, and waste. They can include plasma LDL-C (for cardiovascular risk), fecal fat (for malabsorption), red cell indices (for vitamin deficiencies), and N balance and serum proteins (such as albumin and transthyretin [prealbumin]) for protein–energy status. (Note: These proteins are made in the liver and transport molecules such as fatty acids and thyroxine [see Chapter 29 Section IV A] through blood. Low albumin levels correlate with increased morbidity and mortality in hospitalized patients. The short half-life (2 to 3 days) of transthyretin as compared to that of albumin [20 days] has led to its use in monitoring the progress of hospitalized patients.)

> Nutritional insufficiency can be the result of inadequate nutrient intake (caused, e.g., by an inability to eat, loss of appetite, or decreased availability), inadequate absorption, decreased utilization, increased excretion, or increased requirements.

Nutrition and the Life Stages

Macronutrient energy sources, micronutrients, EFA, and EAA are required at every life stage. Additionally, each stage has specific nutrition needs.

Infancy, childhood, and adolescence

The rapid growth and development in infancy (birth to age 1 year) and childhood (age 1 year to adolescence) necessitate higher energy and protein needs relative to body size than are required in subsequent life stages. In adolescence, the marked increases in height and weight that occur increase nutritional needs. Growth charts (Fig. 27.23) are used to compare an individual's stature (height) and/or weight to the expected values for others of the same age (≤20 years) and sex. They are based on data from large numbers of normal individuals over time. (Note: Deviations from the expected growth curve, as reflected in the crossing of two or more percentile lines, raise concern.)

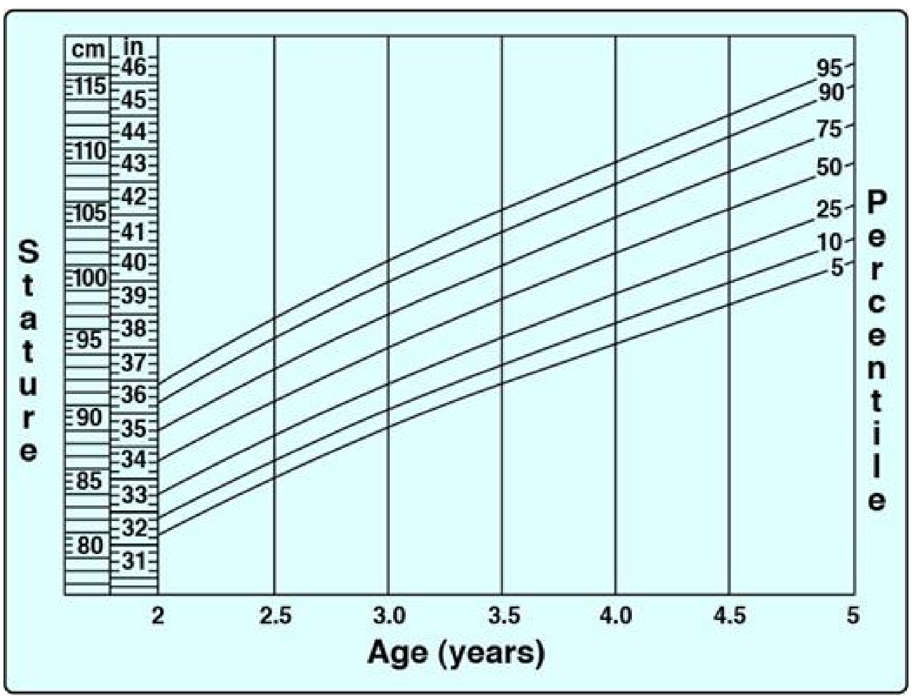
Infants

Ideal infant nutrition is based on human breast milk because it provides calories and most micronutrients in amounts appropriate for the human infant. Carbohydrates, protein, and fat are present in a 7:3:1 ratio. (Note: In addition to the disaccharide lactose, human milk contains nearly 200 unique oligosaccharides. About 90% of the microbiota [the population of microbes] in the breast-fed infant's intestine is represented by one type, *Bifidobacterium infantis*, which expresses all the enzymes needed to degrade these complex sugars. The sugars, in turn, act as prebiotics that support the growth of *B. infantis*, a probiotic [helpful bacteria].) Breast milk is low in vitamin D; however, exclusively breast-fed babies require vitamin D supplementation. (Note: Human milk provides antibodies and other proteins that reduce the risk of infection.)

FIGURE 27.23

Clinical growth chart of stature-for-age for boys age 2 to 5 years from the Centers for Disease Control and Prevention (CDC) (see https://www.cdc.gov/growthcharts/).

Charts for girls are pink.



The microbiota in and on the human body plus their genomes are referred to as the microbiome. It is acquired at birth from the environment and changes with the life stages. The gut microbiome influences host nutrition by facilitating processing of food consumed and is itself influenced by that food. Its relationship with undernutrition, obesity, and diabetes is under investigation.

Children

As with infants, children have increased need for calories and nutrients. The primary concerns in this stage, however, are deficiencies of iron and calcium.

Adolescents

In the teen years, the increases in height and weight increase the need for calories, protein, calcium, iron, and phosphorus. Eating patterns in this stage can result in overconsumption of fat, sodium, and sugar and underconsumption of vitamin A, thiamine, and folic acid. (Note: Eating disorders and obesity are concerns in this age group.)

Adulthood

Overnutrition is a concern in young adults, whereas malnutrition is a concern in older adults.

Young adults

Nutrition in young adults focuses on the maintenance of good health and the prevention of disease. The goal is a diet rich in plant-based foods (with a focus on fiber and whole grains), limited intake of saturated fat and trans fatty acids, and balanced intake of ω-3 and ω-6 PUFA.

Pregnant or lactating women

The requirements for calories, protein, and virtually all micronutrients increase in pregnancy and lactation. Supplementation with folic acid (to prevent neural tube defects [see Chapter 28 Section II 2]), vitamin D, calcium, iron, iodine, and DHA is typically recommended.

Older adults

Aging increases the risk of malnutrition. Decreased appetite resulting from a reduced sense of taste (dysgeusia) and smell (hyposmia) decreases nutrient intake. (Note: Physical limitations, including problems with dentition, and psychosocial factors, such as isolation, may also play a role in reduced intake.) Inadequate intake of protein, calcium, and vitamins D and B_{12} is common. B_{12} deficiency can result from decreased absorption caused by achlorhydria (reduced stomach acid, see Chapter 28 IV). In aging, lean muscle mass decreases and fat increases, resulting in decreased RMR. (Note: Drug–nutrient interactions can occur at any life stage but are more common as the number of medications increases as in aging.)

CLINICAL APPLICATION 27.1

Monoamine Oxidase Inhibitors

Monoamine oxidase inhibitors (MAOIs), used to treat depression (see Chapter 21 Section III A4) and early Parkinson disease, can interact with tyramine-containing foods. Tyramine is a monoamine derived from the decarboxylation of tyrosine during the curing, aging, or fermentation of food (Fig. 27.24). It causes the release of norepinephrine, increasing blood pressure, and heart rate. Patients who take MAOIs and consume such foods are at risk for a hypertensive crisis.

FIGURE 27.24

Decarboxylation of tyrosine to tyramine.

CO_2 = carbon dioxide.

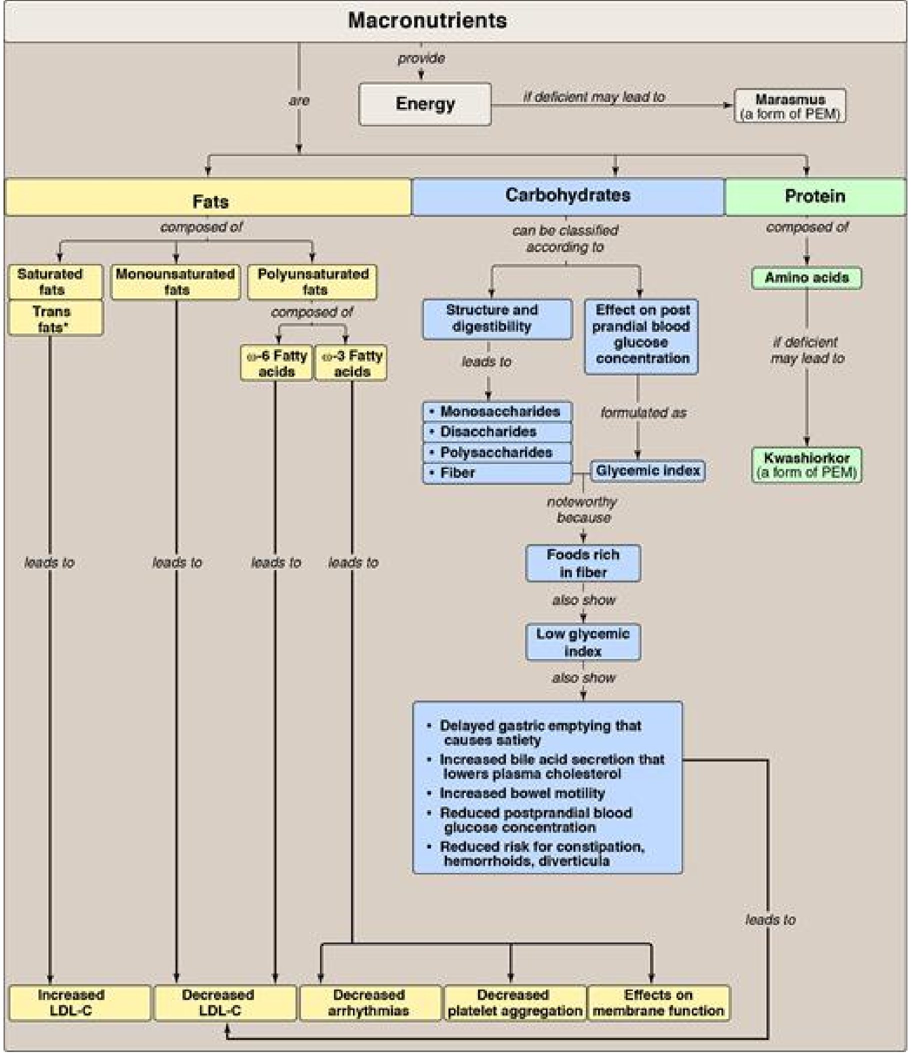
Chapter Summary

- The **Dietary Reference Intakes** (**DRI**) provide estimates of the amounts of nutrients required to prevent deficiencies and maintain optimal health and growth.
- DRIs consist of the **Estimated Average Requirement** (**EAR**), the **Recommended Dietary Allowance** (**RDA**), the **Adequate Intake** (**AI**), and the **Tolerable Upper Intake Level** (**UL**).
- **Estimated Average Requirement** (**EAR**) is the average daily nutrient intake level estimated to meet the requirement of 50% of the healthy individuals in a particular life stage (age) and gender group.
- **Recommended Dietary Allowance** (**RDA**) is the average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97% to 98%) individuals in a life stage and gender group.
- **Adequate Intake** (**AI**) is set instead of an RDA if sufficient scientific evidence is not available to calculate the RDA.
- **Tolerable Upper Intake Level** (**UL**) is the highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population.
- The energy generated by the metabolism of the **macronutrients** (9 kcal/g of fat and 4 kcal/g of protein or carbohydrate) is used for three energy-requiring processes that occur in the body: **resting metabolic rate**, **physical activity**, and the **thermic effect of food**.
- **Acceptable Macronutrient Distribution Ranges** (**AMDR**) are defined as the ranges of intake for a particular macronutrient that are associated with reduced risk of chronic disease while providing adequate amounts of essential nutrients.
- Adults should consume **45% to 65%** of their **total calories** from **carbohydrates**, **20% to 35%** from **fat**, and **10% to 35%** from **protein** (Fig. 27.25).

FIGURE 27.25

Key concept map for the macronutrients.

(Note: *Trans fatty acids are chemically classified as unsaturated.) PEM = protein-energy malnutrition; LDL = low-density lipoprotein; C = cholesterol.



- Elevated levels of cholesterol in low-density lipoproteins (LDL-C) result in increased risk for **coronary heart disease** (**CHD**).
- Elevated levels of cholesterol in high-density lipoproteins (HDL-C) have been associated with a decreased risk for CHD.
- Dietary or drug treatment of **hypercholesterolemia** is effective in decreasing LDL-C, increasing HDL-C, and reducing the risk for CHD.
- Consumption of **saturated fats** is strongly associated with high levels of total plasma and LDL-C. When substituted for saturated fatty acids in the diet, **monounsaturated fats** lower both total plasma cholesterol and LDL-C but maintain or increase HDL-C.
- Consumption of fats containing **ω-6 polyunsaturated fatty acids** lowers plasma LDL-C, but HDL-C, which protects against CHD, is also lowered.
- Dietary **ω-3 polyunsaturated fats** suppress cardiac arrhythmias and reduce plasma triacylglycerols, decrease the tendency for thrombosis, and substantially reduce the risk of cardiovascular mortality.
- **Carbohydrates** provide **energy** and **fiber** to the diet. When they are consumed as part of a diet in which caloric intake is equal to energy expenditure, they do not promote obesity.
- Dietary **protein** provides **essential amino acids**.
- **Protein quality** is a measure of its ability to provide the essential amino acids required for tissue maintenance. Proteins from animal sources, in general, have a higher-quality protein than that derived from plants. However, proteins from different plant sources may be combined in such a way that the result is equivalent in nutritional value to animal protein.

- **Positive nitrogen (N) balance** occurs when N intake exceeds N excretion. It is observed in situations in which tissue growth occurs, for example, in childhood, pregnancy, or during recovery from an emaciating illness.
- **Negative N balance** occurs when N losses are greater than N intake. It is associated with inadequate dietary protein; lack of an essential amino acid; or during physiologic stresses such as trauma, burns, illness, or surgery.
- **Kwashiorkor** occurs when protein deprivation is relatively greater than the reduction in total calories. It is characterized by edema.
- **Marasmus** occurs when calorie deprivation is relatively greater than the reduction in protein. No edema is seen. Both are extreme forms of **protein-energy malnutrition (PEM)**. **Nutrition Facts labels** give consumers information about the nutritional content of packaged foods.
- Medical assessment of nutritional status includes **dietary history**, **anthropometric measures**, and **laboratory data**. Each life stage has specific nutrition needs.
- **Growth charts** are used to monitor the growth pattern of an individual from birth through adolescence.
- **Drug–nutrient interactions** are of concern, especially in older adults.

Study Questions

Choose the ONE best answer.

27.1. For the child shown at right, which of the statements would support a diagnosis of kwashiorkor? The child:

From TknoxB. https://www.flickr.com/photos/tkb/18181998

A. appears plump due to increased deposition of fat in adipose tissue.

B. displays abdominal and peripheral edema.

C. has a serum albumin level above normal.

D. has markedly decreased weight for height.

The correct answer = B. Kwashiorkor is caused by inadequate protein intake in the presence of fair to good energy (calorie) intake. Typical findings in a patient with kwashiorkor include abdominal and peripheral edema (note the swollen belly and legs) caused largely by a decreased serum albumin concentration. Body fat stores are depleted, but weight for height can be normal because of edema. Treatment includes a diet adequate in calories and protein.

27.2. Which one of the following statements concerning dietary fat is correct?

A. Coconut oil is rich in monounsaturated fats, and olive oil is rich in saturated fats.

B. Fatty acids containing trans double bonds, unlike the naturally occurring cis isomers, raise high-density lipoprotein cholesterol levels.

C. The polyunsaturated fatty acids linoleic and linolenic acids are required components.

D. Triacylglycerols obtained from plants generally contain less unsaturated fatty acids than do those from animals.

Correct answer = C. Humans are unable to make linoleic and linolenic fatty acids. Consequently, these fatty acids are essential in the diet. Coconut oil is rich in saturated fats, and olive oil is rich in monounsaturated fats. Trans fatty acids raise plasma levels of low-density lipoprotein cholesterol, not high-density lipoprotein cholesterol. Triacylglycerols obtained from plants generally contain more unsaturated fatty acids than do those from animals.

27.3. Given the information that a 70-kg man is consuming a daily average of 275 g of carbohydrate, 75 g of protein, and 65 g of fat, which one of the following conclusions can reasonably be drawn?

A. About 20% of calories are derived from fats.

B. The diet contains a sufficient amount of fiber.

C. The individual is in nitrogen balance.

D. The proportions of carbohydrate, protein, and fat in the diet conform to current recommendations.

E. The total energy intake per day is about 3,000 kcal.

Correct answer = D. The total energy intake is (275 g carbohydrate × 4 kcal/g) + (75 g protein × 4 kcal/g) + (65 g fat × 9 kcal/g) = 1,100 + 300 + 585 = 1,985 total kcal/day. The percentage of calories derived from carbohydrate is 1,100/1,985 = 55, from protein is 300/1,985 = 15, and from fat is 585/1,985 = 30. These are very close to current recommendations. The amount of fiber or nitrogen balance cannot be deduced from the data presented. If the protein is of low biologic value, a negative nitrogen balance is possible.

27.4. In chronic bronchitis, excessive mucus production causes airway obstruction that results in hypoxemia (low blood oxygen level), impaired expiration, and hypercapnia (carbon dioxide retention). Why might a high-fat, low-carbohydrate diet be recommended for a patient with chronic obstructive pulmonary disease caused by chronic bronchitis?

A. Fat contains more oxygen atoms relative to carbon or hydrogen atoms than do carbohydrates.

B. Fat is calorically less dense than carbohydrates.

C. Fat metabolism generates less carbon dioxide.

D. The respiratory quotient (RQ) for fat is higher than the RQ for carbohydrates.

Correct answer = C. A treatment goal for the chronic obstructive pulmonary disease (COPD) caused by acute bronchitis is to insure appropriate nutrition without increasing the respiratory quotient (RQ), which is the ratio of carbon dioxide (CO_2) produced to oxygen consumed, thereby minimizing the production of CO_2. Less CO_2 is produced from the metabolism of fat (RQ = 0.7) than from the catabolism of carbohydrate (RQ = 1.0). Fat contains fewer oxygen atoms. Fat is calorically denser than is carbohydrate. (Note: RQ is determined by indirect calorimetry.)

27.5. A 32-year-old male who was rescued from a house fire was admitted to the hospital with burns over 45% of his body (severe burns). The patient weighs 154 lb (70 kg) and is 72 in (183 cm) tall. Which one of the following is the best rapid estimate of the immediate daily caloric needs of this patient?

A. 1,345 kcal

B. 1,680 kcal

C. 2,690 kcal

D. 3,360 kcal

Correct answer = D. A commonly used rough estimate of the total energy expenditure (TEE) for men is 1 kcal/1 kg body weight/24 hrs. (Note: It is 0.8 kcal for females.) For this patient, that value is 1,680 kcal (1 kcal/kg/hr × 24 hours × 70 kg). In addition, an injury factor of 2 for severe burns must be included in the calculation: 1,680 kcal × 2 = 3,360 kcal.

27.6. Which one of the following is the best advice to give a patient who asks about the notation "%DV" (percent daily value) on the Nutrition Facts label?

A. Achieve 100% daily value for each nutrient each day.

B. Select foods that have the highest percent daily value for all nutrients.

C. Select foods with a low percent daily value for the micronutrients.

D. Select foods with a low percent daily value for saturated fat.

Correct answer = D. The percent daily value (%DV) compares the amount of a given nutrient in a single serving of a product to the recommended daily intake for that nutrient. The %DV for the micronutrients listed on the label, as well as for total carbohydrates and fiber, are based on their recommended minimum daily intake, whereas the %DV for saturated fat, cholesterol, and sodium are based on their recommended maximum daily intake.

For Questions 27.7 and 27.8, use the following case.

A sedentary 50-year-old male weighing 176 lb (80 kg) requests a physical. He denies any health problems. Routine blood analysis is unremarkable except for plasma total cholesterol of 295 mg/dL. (Reference value is <200 mg.) The man refuses drug therapy for his hypercholesterolemia. Analysis of a 1-day dietary recall showed the following:

Kilocalories	3,475 kcal	Cholesterol	822 mg
Protein	102 g	Saturated fat	69 g
Carbohydrate	383 g	Total fat	165 g
Fiber	6 g		

27.7. Decreasing which one of the following dietary components would have the greatest effect in lowering the patient's plasma cholesterol?

A. Carbohydrates

B. Cholesterol

C. Fiber

D. Monounsaturated fat

E. Polyunsaturated fat

F. Saturated fat

Correct answer = F. The intake of saturated fat most strongly influences plasma cholesterol in this diet. The patient is consuming a high-calorie, high-fat diet with 42% of the fat as saturated fat. The most important dietary recommendations are to lower total caloric intake, substitute monounsaturated and polyunsaturated fats for saturated fats, and increase dietary fiber. A decrease in dietary cholesterol would be helpful but is not a primary objective.

27.8. What information would be necessary to estimate the patient's total energy expenditure?

The daily basal energy expenditure (estimated resting metabolic rate/hour × 24 hours) and a physical activity ratio (PAR) based on the type and duration of physical activities are needed variables. An additional 10% would be added to account for the thermic effect of food. Note that if the patient were hospitalized, an injury factor (IF) would be included in the calculation, and the PAR would be modified. Tables of PAR and IF are available.