10
Human Nutrition

The amount of trans fats per serving is listed on the Nutrition Facts label to allow consumers to monitor and hopefully limit a nutrient implicated in increasing the risk of cardiovascular disease.
New ideas in nutrition are quickly incorporated by the health-conscious segment of society and advertisers looking for a new marketing gimmick. The benefits of several nutritional concepts such as fiber, monounsaturated oils, and low-carbohydrate diets have made headlines and influenced lifestyle changes. All these concepts promise better health and are, in fact, dependent on a greater consumption of plants in the human diet. This chapter will examine human nutritional needs and how plants can satisfy these needs.

**MACRONUTRIENTS**

The basic nutritional needs of humans are to supply energy and raw materials for all the various activities and processes that occur in the body. In addition to the need for water, humans require five types of nutrients from their food supply; three of these are required in relatively large amounts and are called **macronutrients**, consisting of **carbohydrates**, **proteins**, and **fats**. The other two types of nutrients, **vitamins** and **minerals**, are required in small amounts and are known as **micronutrients**. If water were removed, the macronutrients would make up almost all the dry weight of foods.*

Human energy requirements vary with the age, sex, and activity level of the individual, within a wide range of 1,200 to 3,200 kilocalories per day. The current recommendation for Americans is an average daily intake of 2,000 kilocalories or 1,600 kilocalories for women and 2,200 kilocalories for men. (A **calorie** is a measure of energy—technically, the amount of energy needed to raise the temperature of one gram of water one degree Celsius.) Food energy is normally measured in kilocalories (1,000 calories = 1 kilocalorie), which can be abbreviated as kcal or Calories with a capital C. Most dietary guides simply use the term calories, but this book will use the more accurate Calories or kilocalories. Each gram of carbohydrate or protein can supply 4 kilocalories while, for each gram of fat consumed, the amount of energy supplied is more than double, 9 kilocalories. Although all the macronutrients can be used as a source of energy, normally only carbohydrates and fats do so while proteins provide the raw materials, or building blocks, required for the synthesis of essential metabolites, growth, and tissue maintenance. The consequences of undernutrition, malnutrition, and overnutrition for the world’s population are the topics of A Closer Look 10.1—Famine or Feast.

**Sugars and Complex Carbohydrates**

Although carbohydrates are commonly grouped into sugars and starches, recall (see Chapter 1) that these compounds can be chemically classified into **monosaccharides**, **disaccharides**, and **polysaccharides**, based on the number of sugar units in the molecule.

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*All organisms have nutrient needs requiring some compounds in large amounts (macronutrients) and other compounds in smaller amounts (micronutrients). In Chapter 1, we discussed the elements that plants require and used the terms macronutrients and micronutrients to refer to the mineral requirements. When referring to human nutritional needs, these terms take on a different meaning, as discussed here.

**Monosaccharides**

Monosaccharides are the basic building block of all carbohydrates, and glucose is the most abundant of these sugars. During the process of digestion, many carbohydrates are broken down or converted into glucose, which is then transported by the blood to all the cells in the body. Within cells, the process of cellular respiration metabolizes glucose to produce the energy necessary to sustain life. Other common monosaccharides are fructose and galactose, which have the same chemical makeup as glucose, C₆H₁₂O₆, differing only in the arrangement of the atoms within the molecules. In the body, most fructose and galactose are converted into glucose and metabolized as such. In the United States, an inexpensive sweetener for many types of processed foods is high-fructose corn syrup, often preferred because fructose is sweeter tasting than table sugar. Fructose is commonly found in many fruits, unlike galactose, which does not normally occur free in nature.

**Disaccharides**

Disaccharides are composed of two monosaccharides chemically joined together. The most common disaccharide is sucrose, or table sugar, formed from a molecule of glucose and a molecule of fructose. Other disaccharides are the milk sugar lactose (a combination of glucose and galactose) and maltose (formed by two glucose molecules), which is largely found in germinating grains. Table sugar, which primarily comes from sugarcane and sugar beet, is at least 97% pure sucrose with little nutritional value, thereby supplying only calories. (See A Closer Look 4.2—Sugar and Slavery.) During digestion, these disaccharides are broken down to yield their component monosaccharides.

**Polysaccharides**

Polysaccharides, also known as complex carbohydrates, contain hundreds to thousands of individual sugar units, and for the most part, glucose is the only monosaccharide present. The different polysaccharides are distinguished by the way in which the glucose units are joined together, their arrangement, and their number. Starch is the storage form of glucose found in plants; it occurs abundantly in seeds, some fruits, tubers, and taproots. The presence of starch in foods can be traced directly to its plant origin; the starch in white bread or pasta was originally stored in the grain of a wheat plant. The major grain crops (wheat, rice, and corn), the major underground crops (potato, sweet potato, and cassava), and the major legumes (beans and peas) supply the majority of starch in the human diet. In the body, starch is broken down into glucose by enzymes in saliva and the small intestine and is transported by the bloodstream to body cells.

Glycogen is the body’s storage form of glucose, found in the liver and skeletal muscles. When the levels of glucose in the blood are higher than the demands of the cells, the excess is used for the synthesis of glycogen in liver and muscle cells. Only a limited amount of glycogen can be stored as a reserve—no more than a day’s worth of energy needs.
In mid-2006, estimates of the world population size were placed at 6.6 billion, with projections of 7.9 billion by the year 2025 and 9.2 billion by 2050 (box fig. 10.1a). This unprecedented population growth presents many problems related to the production and distribution of sufficient food to meet human nutritional needs. Although global food production has increased during recent decades, chronic hunger and malnutrition are ever-present problems in many developing nations, especially in sub-Saharan Africa and East Asia. Estimates of hunger vary greatly, ranging from 800 million to 1.3 billion people who suffer from undernutrition. In addition, another 2 billion people are malnourished and deficient in vitamin A, iron, or iodine. Undernutrition is defined as an insufficient number of kilocalories to maintain daily energy requirements while malnutrition is a quality deficiency in which one or more essential nutrients is lacking, even though caloric intake may be sufficient. Approximately 20 million deaths each year are attributed to these conditions. The majority of starvation-related deaths are among children, with about half of those dying under the age of five. Starvation is usually the underlying cause of death, but most die of diseases such as diarrhea or measles, which would not be fatal in a properly nourished individual.

Two devastating conditions specifically related to undernourishment and malnourishment are kwashiorkor and marasmus (box fig. 10.1b and c). Kwashiorkor occurs when the diet is deficient in protein but has sufficient kilocalories. It is particularly prevalent after weaning, when a child no longer receives the protein-rich breast milk and is switched to a starchy diet low in protein content or quality or both. Symptoms of kwashiorkor include puffy skin and swollen belly due to edema, a fatty liver, a reddish orange cast to the hair, dermatitis, and listlessness.

Marasmus results from starvation when the diet is low in both kilocalories and protein; other nutrients are probably deficient as well. Sufferers from marasmus are extremely thin and shriveled—literally skin and bones as the muscles of the body, even the heart muscle, are wasted away because muscle protein is digested to supply energy needs. The overt symptoms of both marasmus and kwashiorkor can be reversed if treated in time, but especially in infants and young children, mild mental retardation and stunted growth may be permanent results.

The counterpart to the conditions of undernutrition and malnutrition is overnutrition, in which an excessive intake of food can result in obesity and chronic disease. Currently, a global epidemic of obesity is the chief concern of many public health officials.

The WHO (World Health Organization), which first listed obesity as a disease in 1979, has asked the UN member nations to adopt programs in their home countries to reduce the intake of foods high in fats and sugar. It is ironic that developed nations, which have nearly eradicated many...
nutritional deficiencies, are now faced with a new nutritional threat with the prevalence of overweight and obesity. Developing nations are also experiencing a rise in obesity in certain populations—often at a faster rate than that seen in industrialized nations—at the same time that they are trying to combat the serious problem of undernutrition.

An estimated 31% of U.S. adults (20–74 years) in 2000 are overweight or obese, up from 14% in 1971. This increase is seen for both men and women and across all ethnic, socioeconomic, and age groups. The United States is not alone; obesity has been identified as a growing health problem in the United Kingdom, Australasia, Eastern Europe, the Middle East, the Pacific Islands—all these areas have seen the incidence of obesity more than triple since 1980. The WHO estimates that globally more than 1 billion adults are overweight, with 300 million of them obese. Estimates of obesity vary widely, from below 5% of the population in China and Japan and some African nations, to greater than 75% in urban Samoa.

**Body mass index (BMI)** is the most current method used by health-care professionals and fitness experts to determine if a person’s weight poses a health risk. BMI calculates a person’s body weight in kilograms per squared meter (BMI = body wt in kg/[ht in m]$^2$ or body wt in lbs/[ht in in]$^2$ × 703). Most people are considered overweight if their BMI ranges from 25 up to 30. A BMI of 30 or more indicates obesity; a rating of 40 or greater is indicative of severe obesity. An optimal BMI for most adults is below 25, and a BMI below 18.5 is considered underweight. The average BMI for adults in Africa and Asia ranges from 22 to 23 while a range of 25 to 27 is the norm in North America, Europe, and some Latin American, North African, and Pacific Island nations.

Obesity is associated with a higher risk of many diseases and chronic conditions: type 2 diabetes, hypertension (high blood pressure), cardiovascular disease, stroke, asthma, gallstones, cancers (prostate, breast, and colon), and osteoarthritis. Eighty percent of obese adults suffer from one of these diseases; 40% have two or more. Recently it has been shown that women who are overweight in their 70s have a higher risk of developing Alzheimer’s disease in their late 80s.

The alarming rise in childhood obesity over the past two decades has been documented in many countries: Haiti, Costa Rica, Chile, Brazil, England, Scotland, China, Egypt, Australia, Ghana, Morocco, and others. In the United States, the rate of childhood obesity has doubled and the number of overweight adolescents has tripled during the past two decades. Fifteen percent of children and adolescents (ages 6–19) are classified as overweight or obese. A recent survey of 15 nations found American teens to be the fattest.

The repercussions of childhood obesity can be devastating. As with adult obesity, childhood obesity is linked to numerous complications: hypertension, sleep apnea, asthma, negative self-image, and gallstones, among others. Type 2 diabetes, formerly rare in adolescence, is now on the rise in children, mainly as a consequence of childhood obesity. In some populations, 50% of the newly diagnosed are adolescents. In January 2004, the American Academy of Pediatrics issued the statement that “overweight is the most common medical condition of childhood.”

The global epidemic of obesity appears to be directly related to an energy imbalance. In most cases, obesity is caused by an excessive consumption of energy-rich foods, especially those high in sugar and/or saturated fats, coupled with inadequate expenditure of energy due to the limited physical activity associated with a modern, urban lifestyle. In the United States, some researchers suggest that the prevalence of fast foods in the American diet should take much of the blame for the fattening of Americans. Supersizing a McDonald’s Quarter Pounder with Cheese Extra Value Meal, including fries and a soft drink, adds an extra 360 kilocalories and a supersized total of 1,550 kilocalories for a single meal! Health advocates have suggested class-action lawsuits against fast-food chains that encourage the overconsumption of supersized, high-calorie meals, much as the states have sued the tobacco companies to recoup Medicaid money paid out for tobacco-related diseases. In response, McDonald’s is phasing out giant serving sizes and offering more fruit, salads, and yogurt on their menu. Other people have advocated a sin tax on sugary snack foods and soft drinks to discourage their consumption.

Responding to the nation’s rising obesity rate, the Surgeon General released in 2001 The Surgeon General’s Call to Action to Prevent and Decrease Overweight and Obesity. The report warns that health problems resulting from the current epidemic of obesity could reverse many of the health gains achieved in the United States in recent decades. It details specific steps to educate the American people about obesity-linked health issues and what actions should be taken to reduce the incidence of obesity in the American population. President George W. Bush followed in 2002 with his Healthier U.S. Initiative, which is encouraging Americans to prevent obesity by being physically active every day and making healthier choices in their diets. To this end, public service ads released by the federal government in 2004 are appearing on television to publicize the obesity epidemic and promote healthy eating and exercise.

Recently critics have countered that the so-called obesity epidemic was exaggerated by flawed statistical studies and the media. The research behind the obesity epidemic headlines was heavily funded by the weight loss industry, which may have influenced the results. Newer studies report that there is only a small increase in mortality rates of the mildly obese, and in fact, the underweight, even when smokers are excluded, have a higher death rate when compared to those of normal weight. Critics noted that the researchers who identified obesity as a major cause of death in the U.S. did not consider the impact of recent medical advancements, which have significantly improved the outlook for heart disease, diabetes, and high blood pressure, diseases associated with the obese. Another observation ignored is that obesity can have a protective effect in the elderly. Elderly patients who are mildly obese usually outlive their normal weight cohorts when hospitalized for an extended time. Apparently, a nutritional reserve can be helpful in the recovery process. Colon cancer and postmenopausal breast cancer are slightly elevated in the obese, but lung cancer rates are surprisingly lower. The effects of obesity upon health are probably more complex than once thought, and further research is needed.
Fiber in the Diet

Another important dietary component is fiber, which is derived from plant sources. Although not digestible, it does provide bulk and other benefits. There are many types of dietary fiber: cellulose, lignin, hemicellulose, pectin, gums, mucilages, and others. Cellulose, a principal component of plant cell walls, is another polysaccharide composed of glucose; however, humans do not have the enzymatic ability to break the bonds connecting the glucose molecules in cellulose as they do for starch and glycogen, and thus cellulose passes through the digestive tract as roughage, largely unaltered. Other cell-wall components considered dietary fiber include lignin, pectin, and hemicelluloses. Lignin, a cellwall component in plant cells that have secondary walls, is not a polysaccharide but a complex polymer. Pectins and hemicelluloses, which are cell-wall polysaccharides, form the matrix in which cellulose fibrils are embedded. Pectins also occur in the middle lamella between adjacent cells. Gums and mucilages are exudates from various plants that are used commercially as thickening agents in prepared foods. Cell wall polysaccharides, refined from some species of red and brown algae, can also be considered dietary fiber. Although not digestible by human enzymes, some fiber, especially some hemicelluloses, can be broken down by intestinal bacteria and the nutrients made available to the body.

Dietary fiber can be conveniently grouped into two types, soluble and insoluble, relating to their solubility in water. Insoluble fiber includes cellulose, lignin, and some hemicelluloses while soluble fiber includes other hemicelluloses, pectins, gums, mucilages, and the algal polysaccharides. Soluble fiber is resistant to digestion and absorption in the small intestine, but as soluble fiber enters the large intestine, it is acted upon by naturally occurring bacteria. The bacteria ferment soluble fiber into gasses and products beneficial to health. Butyric acid is one of these products. It is known to stabilize blood glucose levels, which decrease the risk of type 2 diabetes. Butyric acid also has been shown to reduce blood levels of cholesterol, reducing the risk of cardiovascular disease, and to raise the acidity of the colon, which prevents cancerous polyps (small tumorlike growths on the lining of the large intestine) from forming.

Fruits, vegetables, seeds, and whole grains supply most of the fiber in the human diet. Some plants are higher in one or more of these types of fiber and the beneficial effects of high-fiber foods differ, depending on which fiber is abundant. For example, the soluble fiber present as gum in oat bran and as pectin in apples is believed to lower cholesterol levels in the blood. Wheat bran, which is largely cellulose, an insoluble fiber, has no particular cholesterol-lowering ability but seems to be most effective in speeding passage through the colon, which may reduce the risk of colon cancer. Psyllium husk from the seed coat of several species of plantain (Plantago ovata, Plantago arenaria) is an especially valuable dietary fiber because it is a good source of both soluble and insoluble fiber.

A recent study showed that a diet high in fiber and low in fat did not prevent the recurrence of polyps in patients who previously had been diagnosed with colon cancer. A recent study, which tracked the diets of more than 700,000 people for over 20 years, found that those eating the least amount of fiber (less than 10 grams per day) were at an increased risk for colorectal cancer. The study also suggested that fiber from cereals and whole grains, but not fruits and vegetables, is best for slightly lowering the risk of rectal cancer. Physicians and nutritionists still advocate the value of fiber in lowering the risk of obesity, heart disease, and diabetes.

Proteins and Essential Amino Acids

Proteins are a group of large complex molecules that serve as structural components and regulate a large variety of bodily functions (table 10.1). Recall that the constituents of proteins are amino acids; there are 20 naturally occurring amino acids, which can be assembled in various combinations and numbers to make the thousands of different types of proteins. During digestion, proteins may be broken down into their component amino acids by enzymes in the digestive tract and transported in the bloodstream to the liver and body tissues.

**Essential Amino Acids**

The necessary role of dietary proteins is to supply amino acids so that the body can construct human proteins. All 20 amino acids are necessary for protein synthesis, and cells in the human body have the ability to synthesize 11 amino acids from raw materials; the other nine cannot be made by the body. These nine are called the *essential amino acids* (table 10.2 and see fig. 1.10) and must come from the diet. It

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### Table 10.1 Functions of Proteins

<table>
<thead>
<tr>
<th>Type of Protein</th>
<th>Function</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Structural</td>
<td>Support</td>
<td>Collagen and keratin</td>
</tr>
<tr>
<td>Enzymes</td>
<td>Catalysts</td>
<td>Digestive enzymes</td>
</tr>
<tr>
<td>Hormones</td>
<td>Regulation</td>
<td>Insulin</td>
</tr>
<tr>
<td>Transport</td>
<td>Transport substance</td>
<td>Hemoglobin</td>
</tr>
<tr>
<td>Storage</td>
<td>Storage of amino acids</td>
<td>Ovalbumin in egg white, casein in milk</td>
</tr>
<tr>
<td>Contractile</td>
<td>Movement</td>
<td>Actin and myosin in muscles</td>
</tr>
<tr>
<td>Defensive</td>
<td>Protection</td>
<td>Antibodies (immunoglobins)</td>
</tr>
</tbody>
</table>
is important to note that these essential amino acids cannot be stored by the body, and they must be present simultaneously in the diet. For this reason it is critical that the body receives all the essential amino acids in a single day. Persistent lack of these essential amino acids prevents synthesis of necessary proteins and results in protein-deficiency diseases.

**Complete Proteins**

**Complete proteins** contain all the essential amino acids and in the right proportions. Almost all proteins derived from animals are complete proteins whereas proteins derived from plants are usually **incomplete**, deficient in one or more essential amino acids. Although plant proteins are incomplete, the essential amino acid requirements can be met by combining complementary plant proteins. For example, the traditional diet of the native peoples of Mexico, beans and corn, contains complementary protein sources. The beans are low in methionine but adequate in tryptophan and lysine, but corn, which is poor in tryptophan and lysine, contains adequate amounts of methionine.

Although we have an absolute requirement for the essential amino acids, the actual amount of protein required by humans is a small percentage of our nutrient needs. It is recommended that approximately 10% (a range from 8% to 10%) of our total caloric intake be provided by proteins. On the basis of this percentage, individuals on a 2,000-kilocalorie diet should have 50 grams of protein per day; those on a 1,600-kilocalorie diet, 40 grams of protein per day; and those on a 2,200-kilocalorie diet, 55 grams of protein. The following daily protein intakes have been recommended for specific age groups: infants under 1 year—14 grams; children 1 to 4 years old—16 grams; pregnant women—60 grams; and nursing mothers—65 grams. The protein we require can be obtained from many foods. Table 10.3 contains examples of the protein in some common foods.

Proteins can be assigned a numerical value that reflects how well they supply the essential amino acids. The protein in eggs has been assigned a biological value of 100, and all other foods are given values using egg protein as the reference standard. Another factor that needs to be considered is the digestibility of a particular protein. Some proteins cannot be broken down completely; that is, the amino acids are not fully released during digestion. This incomplete breakdown reduces the dietary value of the protein. For example, when digestibility is taken into account even egg protein, considered the perfect protein source, drops to a value of 94. High-quality proteins contain all the essential amino acids in the right proportions and are fully digestible, freeing their amino acids, which are then absorbed into the blood and transported to the body’s cells.
Fatty acids can be separated into two types, formula lacking these essential nutrients. Growth and skin irritation, have been seen in infants fed a lack of the essential fatty acids. Deficiency symptoms, such as poor health and development in children. linearly for those who are consuming a totally fat-free diet, as little as one fatty acid is needed to experience deficiency symptoms because these three fatty acids must be supplied in the diet. Linoleic, linolenic, and arachidonic acids are designated essential fatty acids, but few adults are widely found in foods, especially vegetable oils. Even if an adult were consuming a totally fat-free diet, as little as one fatty acid could be supplied. These end products are absorbed into the intestinal cells where they are resynthesized into new triglycerides that enter the lymphatic system and eventually the bloodstream. High blood triglyceride level is a risk factor for coronary heart disease.

**Essential Fatty Acids**

The body is capable of synthesizing most fatty acids, but three must be supplied in the diet. Linoleic, linolenic, and arachidonic acids are designated essential fatty acids, but few adults suffer deficiency symptoms because these three fatty acids are widely found in foods, especially vegetable oils. Even if an adult were consuming a totally fat-free diet, as little as one teaspoon of corn oil, as an ingredient in foods, would supply the essential fatty acids. Deficiency symptoms, such as poor growth and skin irritation, have been seen in infants fed a formula lacking these essential nutrients.

**Saturated and Unsaturated Fats**

Fatty acids can be separated into two types, saturated and unsaturated. Saturated fatty acids contain all single bonds between the carbon atoms and have the maximum number of hydrogen atoms (it is said to be saturated with hydrogen). Unsaturated fatty acids have one or more double bonds between carbon atoms and consequently fewer hydrogen atoms. Each carbon atom can form only four bonds, so if a double bond occurs between two carbons, then less than the full complement of hydrogen atoms can be attached. A fatty acid with one double bond is called monounsaturated and lacks two hydrogen atoms; a polyunsaturated fatty acid has two or more double bonds and lacks four or more hydrogen atoms (fig. 10.1).

All food fats contain a mixture of both saturated and unsaturated fatty acids (fig. 10.2). Saturated fats contain mostly saturated fatty acids and are solid at room temperature; animal fats such as lard, butter, and beef fat are familiar examples. Vegetable oils are generally composed of unsaturated fatty acids and are liquid at room temperature. Oils containing mostly monounsaturated fatty acids are olive oil, peanut oil, and canola oil; other vegetable oils, such as corn oil, soybean oil, and walnut oil, contain mostly polyunsaturated fatty acids. Coconut oil, palm and palm kernel oils, and cocoa butter are exceptions to the rule. Although they are of plant origin, they consist mostly of saturated fatty acids. On the other hand, certain fish oils are actually unsaturated. The oils from fish such as salmon, tuna, and herring are polyunsaturated and contain omega-3 fatty acids. Omega-3 fatty acids lower the tendency of blood platelets to stick together and form blood clots. Lowering the risk of clot formation reduces the incidence of blocked blood flow to the heart and the onset of coronary heart disease.
The health implications of saturated versus unsaturated fats have been intensely studied by the scientific community. Because saturated fats increase blood cholesterol levels, they are linked to cardiovascular diseases. Unsaturated fats, on the other hand, lower the risk of cardiovascular disease by lowering blood cholesterol levels.

**Cholesterol**

Cholesterol belongs to a subcategory of lipids known as steroids, which are compounds containing four carbon rings (see Chapter 1). Several steroids, including cholesterol, also have a hydrocarbon tail and an –OH group, making them sterols. Cholesterol is a vital constituent of cells; it is part of the lipid component of cell membranes and is also used in the synthesis of sex hormones and several other hormones.

Cholesterol is synthesized in the liver from saturated fatty acids and is also absorbed by intestinal cells from animal foods, especially eggs, butter, cheese, and meat. If the diet is high in saturated fats, even if it is low in cholesterol, the liver responds by increased cholesterol synthesis. Because cholesterol, like all lipids, is insoluble in the watery medium of the blood, it is transported by a special complex that consists of a cholesterol center with a coating of lipids and water-soluble proteins. These transport molecules are known as lipoproteins and exist in several forms. Two of the most significant are the **low-density lipoproteins (LDLs)** and **high-density lipoproteins (HDLs)**. LDLs transport cholesterol to all the body cells while HDLs remove excess cholesterol from the body’s tissues and carry it to the liver for degradation and elimination. In the popular press, the LDLs are considered the “bad” cholesterol because they can be taken up by the cells that line the arteries. The resulting deposition of cholesterol blocks the arteries, restricting the blood flow, and is known as atherosclerosis. This condition can lead to heart attacks if the coronary arteries are blocked and strokes if the arteries delivering blood to the brain are blocked. HDLs are considered “good” cholesterol because they can prevent atherosclerosis by preventing the buildup of cholesterol deposits on the lining of the arteries.

Diet high in cholesterol or saturated fat or both contribute to high blood cholesterol levels, especially in the form of LDLs. Plant sources do not contribute dietary cholesterol directly although, as pointed out previously, some may be high in saturated fats. On the other hand, plant oils are generally rich in unsaturated fats, which are known to lower blood cholesterol levels. However, monounsaturated and polyunsaturated fats act differently. Polyunsaturated fats tend to lower all cholesterol levels, including the protective HDLs whereas monounsaturated fats raise the HDLs while lowering total and LDL levels. LDL blood cholesterol level is a better gauge of the risk of heart disease than is total blood cholesterol; the lower the LDL level, the lower the risk of heart disease. Cholesterol ratio, the ratio of total cholesterol to HDL, is another measure for the risk of heart disease. The ratio should be less than 5 to 1; the recommended ratio is 3.5 to 1 or lower. Although hereditary factors, cigarette smoking, and exercise play a role in the LDL–HDL balance, for the majority of people diet is the single most important factor in controlling cholesterol levels and the inherent disease risks.

**Trans Fatty Acids**

Trans fatty acids occur naturally in foods such as beef, lamb, whole milk, cream, and butter that are derived from ruminant (cud-chewing) animals. Conjugated linoleic acid, a natural trans fatty acid, may be beneficial as an anticarcinogen and in strengthening the immune system. However, most trans fatty acids are made when manufacturers convert liquid oils into solid fats. In this practice, known as **hydrogenation**, vegetable oils are partially or fully hydrogenated to make margarine, vegetable shortening, peanut butter, or salad dressing. **Trans fats** are present in many processed foods, such as crackers, cookies, baked goods, snack foods, and practically any food made with or fried in partially hydrogenated oils.
Trans fats act somewhat like saturated fats, but chemically, trans fats are unsaturated. The carbon-carbon double bonds found in unsaturated vegetable oils are in a *cis* configuration in which the molecular groups attached to each carbon in the double bonds bend in the same direction, either both up or both down. During the hydrogenation process, some of the double bonds are broken and hydrogen is added to the carbons. More significantly, most of the double bonds change configuration from *cis* to the *trans* position. In the *trans* configuration, the molecules attached to each carbon of the double bonds bend in opposite directions or a zigzag fashion. Thus, trans fatty acids can stack closer together, and the transformed oil readily takes on a solid, spreadable form that many consumers prefer over the natural liquid state.

A recently released study of elderly men in the Netherlands indicated that a diet high in trans fat raised blood LDL cholesterol levels while lowering HDL levels. Coronary heart disease was higher in those men who ate more trans fats, and the risk of developing coronary heart disease within 10 years increased by 25% for each additional 2% of trans fats consumed in their diet. The percentage of trans fats in the diets of these men dropped from a high of over 4% in 1985 to just less than 2% in 1995. It is estimated that trans fats make up about 2% to 4% of the typical U.S. diet.

In the Nurses’ Health Study, conducted by the Harvard School of Public Health, nearly 90,000 women filled out detailed questionnaires about their diet every few years for 14 years. The results found no correlation between the onset of type 2 diabetes and the total fat, saturated fat, or monounsaturated fat consumed. There was, however, a significant occurrence of this most common type of diabetes when the women had diets high in trans fats. It was also discovered that a diet high in polyunsaturated oils lowered the risk of type 2 diabetes.

On the other hand, there is evidence that a diet that includes margarine, a common trans fat food, does significantly reduce LDL cholesterol, on average, more than a diet with butter and its component saturated fatty acids. Trans fats should not be avoided by eating more saturated fat. Currently, the Food and Drug Administration (FDA) proposes that trans fats provide no more than 10% of the daily kilocalories obtained from saturated fat.

Since 1983, the FDA has required that saturated fat and dietary cholesterol be listed on food labels. Due to the apparent association between high trans fats in the diet and the higher risk of cardiovascular disease and, in females, type 2 diabetes, the content of trans fats must be listed on the Nutrition Facts panel of food labels in the United States by January 1, 2006.

Manufacturers have responded to health concerns and consumer demand by developing new methods of hydrogenating vegetable oils. Using supercritical carbon dioxide as a solvent and under conditions of higher pressure and lower temperatures, USDA researchers produced a hydrogenated soybean oil with only 10% trans fats. This percentage is lower than the usual 10% to 30% trans fats found in most hydrogenated vegetable oils.

### MICRONUTRIENTS

Like macronutrients, micronutrients are essential for proper nutrition, but they are required in much smaller amounts. While macronutrients make up the bulk dry weight of food, micronutrients constitute only 1% to 2% of the dry weight. There are two categories of micronutrients, the organic compounds known as vitamins and the inorganic compounds, the minerals.

### Vitamins

Many vitamins play roles as *coenzymes* (molecules that are required for the proper functioning of certain enzymes) in many metabolic pathways in the body; others are directly involved in the synthesis of indispensable compounds. Vitamins are classified according to their solubility, with four *fat-soluble vitamins* (A, D, E, and K) and nine *water-soluble vitamins* (eight *B-complex vitamins* and C). The water-soluble vitamins are not readily stored in the body, and any excess is eliminated in the urine; therefore, these are unlikely to become toxic. On the other hand, the fat-soluble vitamins are easily stored in the fatty tissues of the body, and excessive intake can lead to toxicity symptoms. The dietary sources and deficiencies of these vitamins are described in Tables 10.5 and 10.6. The following discussion is limited to vitamins A, D, C, and the B vitamins thiamine, niacin, and B₁₂.

#### Vitamin A

Vitamin A has many roles in the body. One of the best known involves the formation of vision pigments (rhodopsin and others) present in the retina of the eye. Each pigment is composed of a molecule of retinal (a form of vitamin A) and a protein molecule, called an opsin, that differs from pigment to pigment. The pigments are contained in two types of photoreceptor cells, rods and cones, located deep in the retina of the eye. All light stimulates the rods, providing only black and white vision, while the cones are selectively stimulated by different colors, providing the full spectrum of color vision. In dim light or at night, only the rods are used for vision; therefore, a shortage of retinal has especially pronounced

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**Table 10.5**

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Dietary Source</th>
<th>Results of Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Yellow, orange, and dark green vegetables and fruits; dairy products</td>
<td>Night blindness, xerophthalmia</td>
</tr>
<tr>
<td>D</td>
<td>Eggs and enriched dairy products</td>
<td>Rickets</td>
</tr>
<tr>
<td>E</td>
<td>Seeds, leafy green vegetables</td>
<td>Unknown</td>
</tr>
<tr>
<td>K</td>
<td>Leafy green vegetables</td>
<td>Poor blood clotting</td>
</tr>
</tbody>
</table>
A deficiency can therefore affect many different areas in the body. One of the most tragic consequences is a type of blindness known as xerophthalmia, in which severe vitamin A deficiency results in irreversible drying and degeneration of the cornea. This permanent blindness, easily preventable with proper nutrition, is found most frequently among malnourished children in developing nations. In the skin, keratinization results in rough, dry, scaly, and cracked skin, often with an accumulation of hard material around a hair follicle that looks like a permanent goose bump. Other epithelial tissues, such as those in the mouth, gastrointestinal tract, and respiratory system, are also affected by the decrease in mucus production, becoming progressively drier and subject to infection. Vitamin A is additionally involved in dozens of other roles in the body, including normal bone and tooth development and hormone production in the adrenal and thyroid glands.

In food derived from animal sources, especially liver, vitamin A occurs primarily as retinol, which is readily absorbed by the body and converted to retinal. In plant sources, no retinol is present, but a vitamin A precursor, beta-carotene (first isolated from carrots) occurs abundantly in many yellow, orange, and dark green fruits and vegetables (see Chapter 3) and can be split into two molecules of retinol in the body. The importance of beta-carotene as an antioxidant has been investigated. Antioxidants may protect the body against the destructive action of reactive ions called free radicals. Destructive free radicals form when electrons escape from the Electron Transport System during ATP production and combine with oxygen available in mitochondria (Chapter 4). These highly reactive ions can damage the metabolic machinery of the cell, impairing energy production. They may also damage DNA itself, inducing mutations, and they have been implicated in cancer, heart disease, and even the signs of aging.

**Vitamin D**

The primary function of vitamin D is the regulation of calcium and phosphorus levels, especially for normal bone development. Vitamin D helps control the blood levels of these minerals in three ways:

1. the absorption of calcium and phosphorus from food in the gastrointestinal tract,
2. the removal of these minerals from bones to maintain the concentration in the blood, and
3. the retention of calcium by the kidneys.

Vitamin D is unique in that it can be synthesized by the human body on exposure to sunlight; in fact, it has long been called the sunshine vitamin. The precursor (a cholesterol derivative) is manufactured by the liver and transported to the skin where exposure to the sun’s ultraviolet rays converts it to provitamin D; the final steps in the manufacture of active vitamin D occur in the liver and kidneys. The amount of pigmentation in the skin affects the synthesis of vitamin D because pigment blocks ultraviolet absorption. Darker skin requires longer exposure to sunlight to produce adequate amounts of vitamin D. Thirty minutes of sunlight is adequate for light skin while darker skin may require up to three hours. This exposure to sunlight must be achieved with caution since overexposure to the ultraviolet rays in sunlight is linked to higher risk of skin cancer. The Environmental Protection Agency has estimated that the average American today is indoors 93% of the time, in transit 5% (cars, buses, trains), and outdoors only 2% of the time daily. This limited exposure to sunlight makes it essential that the diet contains vitamin D to avoid deficiency symptoms. Vitamin D is not naturally abundant in any food. None occurs in plant sources, but vitamin D does occur in limited amounts in animal sources such as egg yolks, liver, cream, some fish, and butter. Because there is concern about meeting the nutritional needs for vitamin D, especially for children, milk, which does not contain adequate vitamin D, is routinely fortified with this vitamin.

### Table 10.6 Water-Soluble Vitamins

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Dietary Source</th>
<th>Results of Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B&lt;sub&gt;1&lt;/sub&gt; (thiamine)</strong></td>
<td>Whole grains, legumes, seeds, nuts</td>
<td>Beriberi</td>
</tr>
<tr>
<td><strong>B&lt;sub&gt;2&lt;/sub&gt; (riboflavin)</strong></td>
<td>Dairy products, whole grains, leafy green vegetables, poultry</td>
<td>Mouth sores, lesions of eyes</td>
</tr>
<tr>
<td>Niacin</td>
<td>Meat, eggs, legumes</td>
<td>Pellagra</td>
</tr>
<tr>
<td><strong>B&lt;sub&gt;6&lt;/sub&gt; (pyridoxine)</strong></td>
<td>Dried fruits, seeds, poultry, leafy green vegetables</td>
<td>Irritability, muscle weakness, skin disorders</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>Dried fruits, seeds, poultry, leafy green vegetables, nuts</td>
<td>Insomnia, weakness</td>
</tr>
<tr>
<td>Folic acid (folate)</td>
<td>Legumes, whole grains, green vegetables</td>
<td>Anemia, diarrhea, neural tube defects</td>
</tr>
<tr>
<td>Biotin</td>
<td>Legumes, vegetables, meat, egg yolks</td>
<td>Fatigue, dermatitis</td>
</tr>
<tr>
<td><strong>B&lt;sub&gt;12&lt;/sub&gt; (cobalamin)</strong></td>
<td>Meat, eggs, dairy products</td>
<td>Pernicious anemia</td>
</tr>
<tr>
<td>C</td>
<td>Fresh fruits and vegetables</td>
<td>Scurvy</td>
</tr>
</tbody>
</table>
Because of the role of vitamin D in calcium regulation, the deficiency symptoms are most evident in bone formation. The effects of vitamin D deficiency are most pronounced in children and result in a characteristic malformation of the skeleton known as rickets. The bowing of the legs so commonly associated with the condition is just one of many abnormalities of the skeletal system (fig. 10.3). Dark-skinned children who live in northern, smoggy cities are especially vulnerable to developing this deficiency. Once believed to have been eradicated in developed countries, rickets has reemerged in the United States and the United Kingdom. The problem seems to be that breastfed children are not receiving enough vitamin D to absorb the amount of calcium necessary to build strong bones and teeth. Pediatricians are now recommending vitamin D supplements for breastfed infants. Adult rickets, also known as osteomalacia, is rare but does occur in women who have undergone repeated pregnancies, have low calcium intake, and have inadequate exposure to sunlight.

Currently, researchers in nutrition are advocating that the daily recommended dose of vitamin D be raised to 1000 IU* (International Units) per day for adults not only to promote healthy bones but also to prevent certain forms of cancer. Previous studies have shown that colon cancers were higher in the northern United States where exposure to sunlight is the lowest. Recent studies have correlated blood levels of vitamin D in women to colon cancer. Those with the lowest blood levels of the vitamin had double the risk of colon cancer compared to those women who had the highest levels of vitamin D. Preliminary research shows that this trend may also be repeated for type 2 diabetes and other diseases.

Excess vitamin D causes abnormally high levels of calcium in the blood; this condition often leads to calcium deposits in soft tissues such as kidneys and blood vessels. If not caught in time, this may result in irreversible damage to the cardiovascular system, kidney failure, and even death. In excess, vitamin D is the most toxic of all the vitamins. However, this toxicity cannot occur from sunlight or food; it results only when megadoses of the vitamin are administered without medical supervision.

Vitamin C

Fresh fruits and vegetables are the richest sources of vitamin C, ascorbic acid, with organ meats the only significant animal sources. The most important role of vitamin C in the body is in the synthesis of collagen, a connective tissue protein that serves as a “cellular cement,” holding cells and tissues together. Collagen, the most abundant protein in the body, is found in the matrix of bones, teeth, and cartilage and provides the elasticity of blood vessels and skin. Vitamin C also functions as an antioxidant in the body, preventing other molecules from being oxidized (losing electrons). Because vitamin C prevents oxidation, it is sometimes added to packaged foods to extend the shelf life; in a similar manner, orange juice and lemon juice, with their high vitamin C, prevent the oxidation (browning) of sliced apples or bananas. Vitamin C is additionally involved in promoting iron absorption through the intestines. When foods containing vitamin C are consumed with foods containing iron, absorption is enhanced. Finally, vitamin C is involved in a number of other metabolic reactions including the production of various hormones.

For centuries, sailors on long ocean voyages faced the possibility of developing scurvy, a disease that could cause bleeding of the gums, pinpoint hemorrhages under the skin, severe fatigue, poor healing of wounds, brittle bones, and even sudden death due to massive internal bleeding. It was not uncommon for half to two-thirds of the ship’s company to die of scurvy on a long voyage. The first cure for this disease was identified in 1747 by Dr. James Lind, who experimented with 12 seamen afflicted with scurvy. Lind tried various dietary supplements and found that sailors who were given either oranges or lemons for 6 days improved rapidly. Interestingly, it was almost 50 years after these findings that the British admiralty took measures to prevent scurvy by dictating that all sailors receive lemon or lime juice daily. (British sailors were soon nicknamed “limeys” because of this practice, a name that is still heard today.) Now it is well known that the vitamin C in the citrus juice prevented scurvy. The typical symptoms of scurvy can be traced directly to the inability of the body to make collagen. The scurvy–vitamin C connection is reflected in the name ascorbic acid, which literally means “without scurvy.” Since the 1970s, the daily intake of vitamin C has been the focal point of a heated debate after the publication of Vitamin C and the Common Cold by Linus Pauling, a Nobel Prize–winning chemist. The RDI (reference daily intake)* for vitamin C is 60 milligrams (approximately 10 milligrams daily can prevent scurvy), but Pauling recommended

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*International Unit is a unit of measurement for biologically active substances (such as vitamins, hormones, vaccines, etc.) that produces a measured biological effect agreed upon as an international standard.

*Two new nutritional terms now appear on the familiar food label. Daily values are determined by the U.S. FDA (Food and Drug Administration) and indicate the percentage amount of a nutrient that is provided by a single serving of a particular food, based on the current recommendations for a 2,000-kilocalorie diet. There are two categories of daily values: daily reference values (DVRs) and reference daily intakes (RDIs). DVRs have been determined for total fat, saturated fat, cholesterol, total carbohydrate, dietary fiber, sodium, potassium, and protein. RDIs are established for 19 vitamins and minerals and have replaced the older term of recommended daily allowances (RDAs).
megadoses as high as 2,000 to 10,000 milligrams for optimum health. Pauling maintained that large doses of vitamin C can prevent colds and other viral infections and that vitamin C is bactericidal and even cures cancer. Some of these claims have been substantiated, but some authorities believe that tissues become saturated with vitamin C at levels of 80 to 100 milligrams per day and that intakes above these levels are generally excreted in the urine. Controversy also exists regarding the toxicity of vitamin C. Some scientists maintain that high doses are nontoxic; others feel that toxicity can occur. The most common toxicity symptoms are nausea, abdominal cramps, and diarrhea. Another possible complication of megadosing is rebound scurvy, a condition that may occur after an abrupt cessation of these high doses. Symptoms mimic scurvy, even though vitamin C intake is not deficient; these symptoms do not occur if the megadoses are decreased gradually.

**Vitamin B Complex**

The vitamin B complex includes a group of eight vitamins that are often found in foods together and have similar roles in the body; that is, they function as coenzymes, involved in thousands of metabolic reactions. They are found in each cell of the body and must be present for normal cell functioning. For each of these vitamins, specific deficiency symptoms occur when the vitamin is lacking in the diet, but in general, no toxicity symptoms have been reported because excess is excreted in the urine. As is vitamin C, the B vitamins are water soluble and can be leached out during food preparation when excess water is used and discarded. In addition, some of the B vitamins may be destroyed by high temperatures during cooking. Thiamine, niacin, and B12 will be considered because these vitamins may be deficient in plant sources.

**Thiamine** Thiamine, also known as vitamin B1, is part of the coenzyme thiamine pyrophosphate, which is involved in the metabolic breakdown of carbohydrates just before the Krebs cycle. Because of thiamine’s central role in metabolism, the symptoms of thiamine deficiency are profound: fatigue; depression; mental confusion; cramping, burning, and numbness in the legs; edema; enlarged heart; and eventually death from cardiac failure. This thiamine deficiency is known as *beriberi* and was found mainly in the Orient where diets were based mainly on polished or white rice rather than on the whole-grain brown rice that still has the outer bran (husk) intact. The thiamine that occurs in the outer layer of the rice is removed during the polishing process. Beriberi became more prevalent when improved techniques for polishing rice were developed that removed more of the bran and, inadvertently, more of the thiamine. In the 1880s, the thiamine deficiency in the Japanese navy was particularly widespread, with 25% to 40% of the sailors developing beriberi. A Japanese physician, Dr. K. Takaki, observed that few sailors developed the disease when milk, meat, and eggs were added to the normal staple of white rice. Unfortunately, he did not realize that the enriched diet was supplying a nutrient missing in the white rice diet. A few years later a Dutch physician, Dr. Christian Eijkman, studied beriberi in the East Indies; he showed that, in diets based almost exclusively on rice, the consumption of brown rice instead of white rice prevented the appearance of beriberi. It was not until the twentieth century that thiamine deficiency was actually identified as the cause of the disease. Good dietary sources of thiamine include meat, especially pork and liver, whole grains, seeds and nuts, and legumes.

**Niacin** Niacin is the collective term for two compounds, *nicotinic acid* and *nicotinamide*, either one of which is used to form the coenzymes NAD+ and NADP+. Recall the importance of these coenzymes for oxidation-reduction reactions in many energy-yielding metabolic pathways (see Chapter 4). Without these coenzymes, the release of energy from the breakdown of foods cannot occur and cellular death results. Niacin can be supplied directly through foods rich in niacin itself or foods rich in the essential amino acid tryptophan because the body can synthesize niacin from the amino acid. Niacin deficiency, therefore, is coupled with a low-protein diet.

A lack of niacin severely affects every organ of the body, and a severe deficiency disease, *pellagra*, develops. The symptoms of pellagra are referred to as the 4 Ds: dermatitis (skin disorders), dementia (mental confusion), diarrhea, and eventually death if niacin is not supplied. The dermatitis (Fig. 10.4) is characterized by rough, reddened skin with lesions developing in exposed areas; in fact, *pellagra* means “rough skin.” The central nervous system is affected, and confusion, memory loss, dizziness, and hallucinations occur. The gastrointestinal system is also involved, and diarrhea, along with abdominal discomfort, nausea, and vomiting, is common. Another characteristic of the condition is a bright red or strawberry tongue.

Pelagra is especially common in areas where corn is the dietary staple. Outbreaks have occurred in southern Europe, particularly Italy, parts of southern India, and the rural South in the United States where the disease was epidemic early in the twentieth century. It was estimated that 10,000 people died and another 200,000 were afflicted each year. During this period, about half the patients in mental hospitals in the South were suffering from the dementia caused by pellagra.

![Figure 10.4](image-url) Pellagra, caused by a lack of niacin, is characterized by dermatitis of the hands.
Although corn does contain some niacin, it is in a form that makes it unavailable; furthermore, corn is also deficient in tryptophan. However, pellagra was not a problem in the traditional diet of the natives of Mexico, Central America, and parts of South America for two reasons. Lime (calcium oxide from wood ash or shells), used in the preparation of the corn meal, is able to release the bound niacin. In addition, the beans, squash, tomatoes, and peppers commonly eaten with the corn also supplied niacin.

The addition of milk and meat to the diet was recommended to prevent pellagra long before the vitamin was identified. Although meat contains niacin, milk is low in the vitamin but does supply tryptophan. Sources rich in niacin include meat, poultry, fish, eggs, nuts, seeds, and legumes. One way the pellagra in the South could have been prevented was by the consumption of a handful of peanuts every other day, because peanuts are an excellent source of niacin.

In recent years there has been an increased interest in the therapeutic value of megadoses of niacin (the nicotinic acid form) for reducing blood cholesterol levels. Unfortunately, the megadoses can cause some toxicity symptoms, the most common of which is a niacin flush. It produces a temporary warm flush of the skin, with a tingling or stinging sensation. Intestinal irritation and liver damage have also been reported. The other form of niacin, nicotinamide, does not produce those toxicity symptoms, but is not at all effective in lowering blood cholesterol levels.

**Vitamin B_{12}** Vitamin B_{12} (cobalamin) is unique in that it does not occur naturally in any foods of plant origin but occurs only in animal sources where it is widely available. Those who completely eliminate meat, dairy products, and eggs from their diets are at risk of developing a B_{12} deficiency unless vitamin supplements are taken or fortified foods are eaten. Soy milk, breakfast cereals, and meat substitutes are often fortified with B_{12}.

The absorption of vitamin B_{12} in the small intestines requires the presence of a substance secreted by the stomach called an intrinsic factor. Poor absorption of B_{12} has been reported in people who, because of a genetic defect, do not produce the intrinsic factor. This defect most often shows up after the age of 60 when intrinsic factor production becomes impaired. In this case, B_{12} deficiency symptoms show up even though there are sufficient quantities in the diet, and the vitamin must be received by injection.

The most common result of B_{12} deficiency is pernicious anemia, characterized by the production of improperly formed red blood cells. The associated symptoms include fatigue and weakness because the delivery of oxygen to the body’s tissues is impaired. A more serious consequence of B_{12} deficiency is nerve damage that begins as a creeping numbness of the lower extremities.

In general, vitamin B_{12} is involved in nucleic acid synthesis and interacts with folic acid (another B vitamin) in this function. Because blood cells are constantly being formed in the bone marrow, this site of rapid cell division is one of the first affected by impaired synthesis of DNA due to a deficiency of either vitamin. These vitamins are, therefore, involved in the normal development of red blood cells, and a deficiency of either vitamin causes anemia. The anemia can be treated by either B_{12} or folic acid supplements. However, folic acid supplements have no effect on the nerve damage caused by a B_{12} deficiency, and the administration of folic acid for the anemia can mask a true B_{12} deficiency and result in permanent neurological degeneration. In this regard, vitamin B_{12} functions in maintaining the sheath surrounding nerve fibers, which is necessary for the transmission of nerve impulses.

Under directions from the FDA and the Department of Health and Human Services, U.S. manufacturers fortify most enriched breads, flours, corn meals, rice, and other grain products with folic acid. This action was taken because it was determined that insufficient levels of folic acid contribute to spina bifida (the backbone does not form properly, leaving the spinal cord exposed) and other neural tube birth defects. Because more than half of all pregnancies are unplanned and these defects of the spine and brain occur in the developing fetus before most women realize they are pregnant, it is important that all women of child-bearing age consume 0.4 milligram of folic acid daily. Since 1998, when folic acid fortification of foods began, the number of neural tube birth defects in the United States has dropped by one-third.

Adequate levels of folic acid may also afford protection from early heart disease. In patients with atherosclerosis, high levels of plasma homocysteine are commonly found. Homocysteine is an intermediate in amino acid metabolism. It is toxic to the lining of blood vessels, bringing about changes that lead to cardiovascular disease. It may also promote clotting factors in the blood. Normally, homocysteine is not found in high levels in the bloodstream because it is broken down by enzymatic activity. Certain vitamins, and folic acid is one, are cofactors for these enzymes. Many patients with early coronary artery disease have low levels of folic acid and correspondingly high levels of homocysteine. Increasing the nutritional intake of folic acid will decrease homocysteine levels as well as the risk of heart attack or stroke.

**Concept Quiz**

Vitamins are classified according to their solubility. The water-soluble vitamins include C and the B complex. A, D, E, and K are the fat-soluble vitamins.

Many people subscribe to the notion of vitamin megadosing to ensure better health and consume many times the RDI for particular vitamins. What are the practical effects of vitamin solubility on this practice?
Minerals

Minerals are inorganic compounds that exist in the body as ions (charged atoms) or as part of complex molecules. At least 17 minerals are required for normal metabolic activities (table 10.7), and some, known to be essential for other animals, may be added to the list as research continues. Minerals are subdivided into two categories, the **major minerals**, needed in amounts greater than 100 milligrams per day, and the **trace minerals**, needed in amounts no more than a few milligrams per day. The following discussion will be limited to **calcium**, a major mineral whose RDI has been recently revised, and two trace minerals that have been extensively studied, **iron** and **iodine**.

**Calcium**

Calcium is the most abundant mineral in the body, with the average adult containing 800 to 1,300 grams of the element. Ninety-nine percent of the body’s calcium is found in the bones and teeth; the other 1% is in the blood and tissues. The concentration of calcium is under the control of several hormones and vitamin D. If the amount in the blood gets too low, calcium reserves in the bone are drawn upon to restore levels to the normal range. If the amount of calcium in the blood is too high, more calcium is deposited in the bone and more is excreted by the kidneys. Excess calcium intakes (12,000 milligrams per day and above are considered toxic) have been associated with increased risk of kidney stone formation. In addition to forming the matrix of bones and teeth, calcium in the body fluids is involved in many important functions: nerve impulse transmission, muscle action including heartbeat, blood clotting, cell membrane integrity, intracellular communication, and as a **cofactor** for enzymes (cofactors are mineral ions and, like coenzymes, are necessary for the proper functioning of certain enzymes).

Calcium deficiency may lead to **osteoporosis**, a degenerative bone disease that may strike older individuals without warning. In osteoporosis, the bone density is greatly reduced (**osteoporosis** literally means “porous bone”), resulting in bones that fracture readily. This condition can result from years of low dietary calcium intake or poor absorption of calcium from the intestines (caused by lack of vitamin D or other factors). To maintain blood calcium levels, the reserves in the bone are dangerously depleted. Postmenopausal women are particularly at risk for developing osteoporosis because bone loss is accelerated at this time. Estrogen replacement therapy appears to retard this bone loss. Adequate dietary calcium and regular exercise also prevent osteoporosis; however, there are many interacting factors (both genetic and environmental), and much more research is needed in this area.

Milk and milk products are among the best sources of calcium, but the element is also present in dark green leafy vegetables, many seeds, and other foods. Unfortunately, in some vegetables, the presence of oxalic acid inhibits the absorption of calcium. Recently the RDI for dietary calcium for adults over 50 has been increased to 1,200 milligrams to prevent the development of osteoporosis. New evidence has also shown that calcium, together with vitamin D, may provide protection against colon cancer; the amount of calcium required for this beneficial action is 1,500 milligrams per day.

**Iron**

Although most of the trace minerals are usually found in adequate amounts in a well-balanced diet, iron and iodine present special problems. Iron deficiency is common in women and children, and care must be taken to ensure that the diet supplies sufficient quantities of the element. Meat, especially liver and other organ meats, shellfish, fish, and poultry are excellent iron sources. Many foods from plants are also rich in iron, including dark green leafy vegetables, dried fruits,
legumes, whole grains, and enriched breads and cereal products. Overall, only about 10% of the dietary iron is actually absorbed by the body, with the absorption dependent on the type of iron compound present; the rest is eliminated in the feces. The iron from animal sources may be present as heme iron (40%) or nonheme iron (60%) whereas the iron in plant sources is nonheme. Heme iron is more readily absorbed by the body, but the absorption of nonheme iron can be improved by the presence of vitamin C.

The most important role of iron is as a component of hemoglobin, the molecule that carries oxygen in red blood cells; in fact, it is the iron that imparts the red color to these cells. In addition, iron occurs in myoglobin, a molecule similar to hemoglobin, the oxygen carrier in muscle cells; in several storage proteins in the liver, bone marrow, and spleen; and in enzymes present in each cell.

Because the majority of iron is found in hemoglobin, iron deficiency has its greatest impact on red blood cells. When iron reserves in the body are low, not enough hemoglobin can be synthesized for newly formed red blood cells. These cells are smaller, paler, and less efficient in oxygen transport than are normal red blood cells and are characteristic of iron deficiency anemia, the most common dietary deficiency disease in the world. The symptoms of iron deficiency anemia include fatigue, inability to concentrate, pale coloration, weakness, and listlessness.

The greatest risk of iron toxicity comes from overdosing on iron supplements, which can result in damage to the liver and pancreas and even sudden death in young children.

Iodine

The presence of iodine in food is dependent on the availability of iodine in the natural environment where the plant or animal developed. Foods from the ocean are reliable sources of iodine because this element is plentiful in seawater. In general, inland areas, especially mountainous regions, are likely to have iodine deficient soils. It is in these areas where people may develop the iodine deficiency disease endemic, or simple, goiter. In the United States, the area around the Great Lakes was formerly known as the “goiter belt” because of the high incidence of goiter. The most obvious symptom of goiter is a swelling of the neck caused by an enlargement of the thyroid gland, which straddles the trachea.

Iodine is required for the formation of thyroid hormones that regulate metabolism in all cells of the body and control body temperature, growth, development, and reproduction. When the amount of iodine is low, hormone production is impaired. The thyroid enlarges in an attempt to produce more of the needed hormones; this attempt is futile without the necessary iodine. A person suffering from simple goiter exhibits a lack of energy, decreased blood pressure, sensitivity to cold temperatures, and weight gain.

Goiter has been a recognized ailment since ancient times, and various treatments have been suggested as a cure. The earliest known treatment is recorded in a Chinese source from 5,000 years ago that recommended eating seaweed and burned marine sponge. Today it is known, of course, that organisms from the ocean are naturally rich in iodine. The relationship between iodine and goiter was confirmed in 1820 by the French physician Coindet, who reported the treatment of goiter using doses of iodine salts. Today goiter is rare in the United States and Europe because of iodized table salt, first introduced in 1924. However, in other areas of the world, almost 200 million people still suffer from goiter, an easily preventable disorder.

More than half of the salt sold in the United States is iodized, and a single teaspoon of this salt supplies almost twice the RDI of 0.15 milligram. However, overconsumption of iodine-containing substances can also be a problem because iodine can be toxic. As little as 2.0 milligrams per day is considered toxic, resulting also in an enlargement of the thyroid gland.

In addition to a lack (or even an excess) of dietary iodine, goiter can result from the overconsumption of goitrogenic compounds. Certain medications, including some of the sulfa drugs, and vegetables in the cabbage family are known to contain compounds that block the utilization of iodine in the thyroid. In a varied diet, these compounds are harmless, but they may be a problem in diets restricted solely to those vegetables.

**Concept Quiz**

The macronutrients (carbohydrates, proteins, and fats) are required in relatively large amounts for proper nutrition whereas the micronutrients, the vitamins and minerals, are needed in smaller quantities.

> Since micronutrients are required in much smaller amounts than macronutrients, are they any less important to the human diet? 
> Explain.

**DIETARY GUIDELINES**

Research has shown that many significant diseases are influenced by nutrition, and beneficial changes in diet can, therefore, reduce the risk of developing these conditions. Diseases linked to nutrition are some of the major causes of death in the United States: cardiovascular diseases, hypertension, some forms of cancer, and type 2 diabetes. These diseases may arise in part from excess consumption of fat, especially saturated fat, cholesterol, refined sugar, and salt. In light of these findings, governmental agencies and health professionals have recommended dietary guidelines for better health and the prevention of disease.
Balancing Nutritional Requirements

The U.S. Senate Select Committee on Nutrition and Human Needs issued the first Dietary Goals for the United States in 1977. This was followed in 1980 by the publication of Nutrition and Your Health: Dietary Guidelines for Americans, issued jointly by the U.S. Department of Health and Human Services (HHS) and the U.S. Department of Agriculture (USDA). Revisions of the Dietary Guidelines have followed every 5 years. The latest revision of the USDA Food Pyramid was released in 2005, and includes some major changes (fig 10.5). Some of the recommendations for the sixth edition, are as follows:

1. Make half your grains whole. Eat at least three ounces of whole grains every day.
2. Vary your vegetables. Eat more dark green and orange vegetables. Eat more dry beans and peas.
3. Eat a variety of fruit, but reduce the consumption of fruit juices.
4. Know your fats. Make most of your fat sources from fish, nuts, and vegetable oils. Limit the eating of solid fats.
5. Get your calcium from low-fat or fat-free milk and dairy products.
6. Choose low-fat or lean meats and poultry. Prepare by baking, broiling, or grilling. Eat more fish, beans, peas, nuts, and seeds for protein.
7. Find your balance between food and physical activity. Be physically active at least 30 minutes (children and teens 60 minutes) most every day.

The dietary guidelines originally suggested that complex carbohydrates should make up about 60% of the daily caloric intake, proteins about 8% to 10%, and fats no more than 30%, with 10% each from saturated, monounsaturated, and polyunsaturated fat sources. Since the first dietary guidelines were issued, some healthy trends have developed among the American people. Fresh fruits, vegetables, and whole grain products have undergone a resurgence in popularity owing to expanded selections available in the supermarkets and increased nutritional awareness of the value of fiber.

Although the goals called for a reduction in the consumption of refined and processed sugars, the consumption of these sugars has continued to rise (a trend that began early in the twentieth century). At least part of the recent rise is attributable to the increased consumption of soft drinks, which contain high fructose corn syrup. One positive sign, however, is the continuing switch to diet beverages.

Figure 10.5  The 2005 USDA MyPyramid illustrates the daily recommended proportions for the six food groups by the width of each band at the base. The figure climbing the steps of the pyramid is a reminder to exercise daily.
Americans are eating less red meat, eggs, and whole dairy products than ever before, which is a good trend for reducing saturated fats and cholesterol. Consumption of poultry and fish has increased as consumption of beef has declined, and low-fat dairy products have become the preferred choice for many people. Although the intake of saturated fat has decreased (dramatically for butter and lard), more plant oils are being consumed. This trend has had a significant agricultural impact as farmers have increased the acreage devoted to growing oil crops such as sunflower, safflower, rape seed (canola oil), corn, and soybean. Margarine, shortening, salad oils, and cooking oils account for the expanded use of plant oils, but remember, if the plant oils are hydrogenated, they have reduced health value.

Since the early 1980s, there has been a heightened awareness about the dangers of high blood cholesterol levels, and Americans have responded with changes in diet and exercise. A report on several thousand men and women showed a decrease in cholesterol levels: for men, the 1980–1982 average was 205 milligrams, lowered to 200 milligrams in the 1985–1987 study; likewise, women showed a drop from 201 milligrams to 195 milligrams in the same period. This trend indicates that many Americans are attempting to keep blood cholesterol at or below the recommended level of 200 milligrams.

Although sodium is one of the major minerals, most Americans ingest more sodium (in the form of sodium chloride—table salt) than required; high sodium intake is related to hypertension (high blood pressure). Excessive salt ions in the bloodstream draw water from the tissues, thereby raising the fluid pressure in the blood vessels. A low-salt diet may be effective in lowering blood pressure in sodium-sensitive individuals. Some foods naturally contain sodium, but much of the sodium in our diet generally comes from prepared foods. In fact, two-thirds of dietary salt is actually “hidden” in commercially prepared food and beverages.

**A Healthier Food Pyramid**

In February 2004, the CDC (Centers for Disease Control and Prevention) released the results of a study on the prevalence of obesity and the changes to the American diet over the past 30 years. The incidence of obese individuals in the total U.S. adult population increased from 14.5% in 1971 to nearly 31% in 2000 as the average amount of kilocalories per day rose. For men, the average energy intake increased from 2,450 in 1971 up to 2,618. The rise in energy intake for women was nearly double that at 335 kilocalories. As many low-carbohydrate dieters suggest, the rise in obesity in the United States appears to be correlated with a rise in carbohydrates, especially refined starches and sugars.

This trend is especially disheartening because earlier versions of the USDA Food Pyramid have advised Americans since 1992 to minimize consumption of fats to just 30% per day and increase complex carbohydrates such as breads, cereals, rice, and pasta to 60% of the daily diet. Other directives were to limit dairy products and protein sources (meat, eggs, fish, poultry, and beans) to two to three servings for each group per day and increase the number of servings of fruits and vegetables eaten daily.

The most controversial aspect of previous food pyramids was the advice about fats and carbohydrates. Many researchers are coming to the conclusion that it is just too simplistic to advocate eating all types of complex carbohydrates and avoid all types of fats. Increasingly, it has been shown that there is no nutritional evidence that a diet high in complex carbohydrates and low in all fats is beneficial to health. In fact, the reverse may be true.

Although it is known that a diet high in saturated fats raises total blood cholesterol levels and that high cholesterol is associated with an increased risk of coronary heart disease, certain fats, as stated previously, are beneficial to health. Monounsaturated fats such as olive oil can reduce the risk of cardiovascular disease by lowering LDL cholesterol levels and raising HDL cholesterol. It has been also shown that a diet of polyunsaturated fats can reduce total blood cholesterol levels.

For example, the so-called Mediterranean diet common in Italy, France, and Greece, in which fats make up 40% of the total kilocalories, is associated with a low rate of heart disease. Apparently, the type of fats—mainly monounsaturated olive oil and polyunsaturated fish oils with omega-3 fatty acids—not the percentage, is the determining factor in lowering the incidence of heart disease.

The original intent of the earlier USDA Food Pyramid was to influence the American public to decrease consumption of saturated fats. At the time, it was thought to be too difficult for the public to distinguish saturated fats from other types of fats, so the message was simplified to decrease consumption of all fats to 30% of total kilocalories, down from the 40% typical of the American diet. To compensate for the kilocalories lost by decreased fat consumption, the percentage of complex carbohydrates was raised from 45% to 60%.

The recommended daily percentage of protein stayed about the same at 10% to 15% because there was concern that if increased protein consumption was recommended, people would eat more red meat as a protein source without realizing that red meat is usually associated with saturated fat. “Fats are bad” was the rallying cry of the earlier Food Pyramid.
Unfortunately, this message was the wrong one. Nutritional studies from the early 1990s have shown that if people replace kilocalories from saturated fat with an equal amount from carbohydrates, their LDL and total cholesterol levels do fall, but so does their level of HDL. Similarly, if people eat a diet high in monounsaturated or polyunsaturated fats but then switch to an equivalent amount of kilocalories from carbohydrates, their LDL levels rise and HDL levels decline.

Trans fatty acids found in many dietary substitutes for foods rich in saturated fats are uniquely bad because they raise LDL and triglycerides while reducing HDL. Eating trans fatty acids increases the risk of cardiovascular disease greatly. In contrast, consuming saturated fats increases the risk only slightly because consumption of saturated fats increases LDL but also HDL.

Another common misconception is that eating a greater percentage of fats in the daily diet is linked to obesity because fats have more than double the kilocalories of equal portions of proteins or carbohydrates. The standard advice has been to avoid obesity by eating a low-fat diet. The only way to avoid obesity is to lower total kilocalories, not just fat kilocalories, and increase energy expenditure through physical activity.

No nutritional studies have definitively linked the consumption of fat with a higher risk of breast or colon cancers. A diet high in red meat has been associated with a higher risk of colon cancer, but this link is probably due to carcinogens produced during cooking and the type of chemicals found in processed meat. A low-fat diet has not been shown to reduce the risk of cancer. A 2006 study on women’s health compared women who reduced fat consumption from 8% to 10% over a period of eight years with a control group. They found that the rates for colon and heart disease were not statistically different, but the rate of breast cancer showed a small decline.

Incorporating weight control and physical activity appear to be the key factors in decreasing the risk of many cancers. Unfortunately, recent data did find that sedentary, overweight women who ate diets high in refined carbohydrates had a high incidence of both pancreatic and breast cancer. Increasingly, evidence points out that a diet high in certain carbohydrates is not synonymous to healthy eating.

Some carbohydrates are readily digested and quickly metabolized by the body into glucose. A rapid increase in blood glucose stimulates the release of insulin from the pancreas. Insulin facilitates the uptake of glucose into body cells, such as muscle and fat cells, and quickly lowers blood sugar levels. Glycemic index (GI) measures the effect that a particular food has on blood glucose levels. The faster the food is converted to glucose, the higher the GI number. White bread, white rice, and white potatoes are examples of carbohydrates with relatively high GI values. Whole grains, and high-fiber fruits and vegetables have lower GI ratings. A more practical measure that is often used is glycemic load, which takes the GI value for a food and multiplies it by the number of carbohydrate grams the food contains. Thus, many fruits and vegetables that have a relatively high GI value have a much lower glycemic load. Fiber slows the rate of digestion, and high carbohydrate foods, such as many beans, that also are high in fiber will have a lower GI.

There are difficulties in accurately determining the GI for a particular food because the calculation is based on the average blood glucose response of 10 subjects after they have eaten a particular food. Different people have different responses to the same food, and the same person may have a different response on a different day. Eating different combinations of foods or changing the method of cooking can also alter the GI value.

A diet high in GI food is associated with a greater risk of heart disease, type 2 diabetes, and obesity. A diet high in GI carbohydrates raises blood triglyceride levels and lowers HDL cholesterol, increasing the risk of coronary heart disease. Another consequence of a diet in high GI foods is insulin resistance, common in many overweight, sedentary people. One of the main indicators of insulin resistance, also known as Syndrome X, is a sustained high blood glucose level after the ingestion of high GI foods. Although insulin is produced in affected individuals, it is not as effective in moving glucose from the bloodstream into body cells. Because the insulin is not as effective, more and more insulin is released to do the job of moving glucose out of the blood and into cells. Eventually, the insulin-producing cells of the pancreas become overtaxed by higher production levels and give out. People who exhibit insulin resistance have a higher risk of hypertension, heart disease, and most significantly, type 2 diabetes. Foods with the highest GI numbers correspond with greater insulin release, and the higher the insulin spike, the lower the blood glucose sinks. Low blood glucose stimulates hunger and a craving for more high GI foods, which may lead to overeating and weight gain. In contrast, low GI foods are digested more slowly, glucose levels in the blood drop gradually, and it takes longer for hunger to return.

Another problem with the previous USDA Food Pyramid was that it did not distinguish between different sources of protein. It lumped red meat, poultry, fish, legumes, nuts, and eggs into a single group despite the evidence that a diet high in red meat is high in saturated fats and cholesterol and is associated with an increased risk of coronary heart disease and type 2 diabetes. Poultry and fish possess fewer saturated fats but then switch to an equivalent amount of kilocalories of foods or changing the method of cooking can also alter the GI value.

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Cancer has been a dreaded disease for centuries, and it continues to plague humanity today. The term cancer actually refers to over 100 forms of a disease that can strike just about every tissue or organ in the body that shares several basic processes. Cancer cells are abnormal cells that proliferate uncontrollably, forming masses called tumors. Cancer cells also possess the ability to migrate, or metastasize, from the original site, forming tumors in other parts of the body. It is the interference of malignant tumors to normal body functioning that makes cancer lethal.

A number of agents have been identified as carcinogens (cancer-causing agents)—certain microbes, ultraviolet radiation, chemicals (such as PCBs, arsenic, benzene), radon, and various gene mutations—but more than half of all cancers in the United States are related to tobacco smoke and diet. In addition to tars, a number of known carcinogens are found in tobacco smoke (Chapter 20). Not surprisingly, smoking—especially cigarette smoking—is associated with several cancers: lung, upper respiratory tract, esophageal, bladder, and pancreatic. Tobacco smoke is also implicated in stomach, liver, kidney, and pancreas cancers and in leukemia.

Diet is second only to smoking as a major cause of cancer in the United States. Red meat has been identified as an associative cause of colon, rectal, and prostate cancers. Obesity in adults is linked to cancers of the uterus, breast, colon, kidney, and gallbladder. Abusive drinking of alcoholic beverages enhances the risk of cancers of the upper respiratory tract, digestive tract, and liver. Eating heavily salted foods and drinking extremely hot beverages have been linked to cancers of the stomach and esophagus, respectively, in countries outside the United States where these dietary habits are customary.

Ironically, the latest research suggests that what is missing in our diets may be far more important in causing cancer than what we actually eat or drink. Components called phytochemicals, which occur naturally in vegetables, fruits, grains, and seeds, have been investigated for their protective action in the prevention of cancer and other diseases.

Cruciferous vegetables (broccoli, cauliflower, cabbage, and so on) are excellent sources of one class of chemopreventive chemicals: the dithiolthiones. In laboratory animals treated with a synthetic version of one of the dithiolthiones, tumors of the lung, colon, mammary glands, and bladder were inhibited. One of the most potent dithiolthiones is sulforaphane, found in broccoli, which has been shown to inhibit breast cancer in rats. Both of these phytochemicals apparently work by activating liver enzymes that destroy carcinogens in the body.

Genistein, a compound found in soy products (derived from the soybean), prevents the formation of breast tumors in rats in a different manner. It inhibits the formation and growth of blood vessels to a growing tumor. Without these sources of nutrients and oxygen, the tumor cannot grow.

Studying populations that drink quantities of green tea (made from unfermented tea leaves, Chapter 16) has revealed a lower incidence of many cancers, especially those of the breast and prostate. Green tea contains a high percentage of chemical agents (flavonoids) known as catechins, and in particular, epigallocatechin gallate. For a cancer to metastasize, certain enzymes are needed. One of these crucial enzymes is urokinase, and it appears that catechins inhibit it and thus prevent the invasion and spread of cancer cells to distant sites. In the processing of black tea, the type of tea most commonly drunk by Americans, epigallocatechin gallate is destroyed and thus does not afford the same protective benefits associated with the drinking of green tea.

Phytochemicals appear to be most effective if eaten in foods rich in these cancer-preventive agents rather than administered as supplements. In fact, the National Cancer Institute initiated 5 - A - Day Program in 1991 to encourage the public to eating five or more servings of vegetables and fruits every day. Several studies appear to support this belief. Beta-carotene, the yellow-orange pigment associated most commonly with carrots, was given to people at risk for developing lung cancer as a supplement in a chemoprevention trial sponsored by the National Cancer Institute. Surprisingly, the group given beta-carotene had a slightly higher rate of lung cancer than the group given a placebo. A 2007 review of nearly 70 studies also found that adults who take supplements of beta carotene, vitamin A, and/or vitamin E had higher mortality rates than those who did not or who were given a placebo. Adults who took supplements of vitamin C or selenium showed no difference in death rates than the control group.

Recent large, long-term studies looking at a diet high in fruits and vegetables to reduce the risk of breast cancer have failed to substantiate the promise of earlier laboratory work. Those who consumed the greatest amount of fruits and vegetables did, however, show a 25% reduction in the risk of cardiovascular disease. Critics point out flaws in questionnaires and the difficulties that participants have in accurately recording and quantifying their diets. Also, some suggest that the protective effect may be conferred during a critical period in childhood, but no study has examined the connection between a girl’s diet and breast cancer. Another study found that women who had the highest blood concentration of carotenoids, such as beta-carotene, showed the lowest incidence of breast cancer. But the same study showed no difference in the incidence of breast cancer with the amount of vegetables and fruits consumed, suggesting that individual differences in metabolism to harvest protective phytochemicals may be more important. The work continues.
An improved Food Pyramid, as suggested by Walter Willett of the Harvard School of Public Health, emphasizes keeping one’s weight under control through daily exercise and avoiding an excessive total intake of kilocalories. It recommends that the majority of one’s daily diet should be the consumption of the healthy monounsaturated and polyunsaturated fats and healthy carbohydrates, whole grain and unrefined. A variety of fruits and nonstarchy vegetables with protective phytochemicals should be eaten in abundance. Healthy protein sources, such as nuts, legumes, fish, poultry, and eggs, should be eaten in moderation. Dairy products should be limited to one or two servings daily. The consumption of red meat, saturated fats, refined grains, and starchy fruits and vegetables should be restricted. Trans fatty acids should be avoided completely. A daily multiple vitamin and mineral supplement should be taken. Alcohol consumption of beer, wine, or distilled spirits in moderation is acceptable because of evidence of its benefit to the cardiovascular system (see Chapter 24).

Recently Willett conducted a study on the health of men and women who followed his new and improved version of the Food Pyramid. He found that they had reduced the risk of cardiovascular disease by 30% for women and 40% for men. These findings call for dramatic changes in the USDA Food Pyramid and in our diets so that many Americans may have a healthier future.

**Meatless Alternatives**

With the awareness about the dangers of saturated fat and cholesterol inherent in animal products, many Americans are incorporating a greater percentage of vegetables, fruits, grains, and legumes in their diet. Some even choose a totally vegetarian lifestyle. There are many different forms of vegetarianism: **lacto vegetarians**, **lacto-ovo vegetarians**, and **vegans**. Some vegetarians, such as the lacto and the lacto-ovo, consume dairy products or dairy products and eggs but do not consume animal flesh. Vegans are pure vegetarians, consuming no animal products at all. Some other vegetarians stretch the concept by consuming fish and poultry, only avoiding red meat.

There are several health benefits to increasing the consumption of plant products while decreasing the consumption of animal products. Vegetarians are less likely to suffer from chronic diseases that afflict many Americans whose diets are high in animal products. Blood cholesterol and triglyceride levels usually reflect the amount of animal fat in the diet and are lowest in vegans, who, consequently, have a lower incidence of heart disease. Those cancers linked to red meat and dairy consumption (colon and prostate) are less common in vegetarians. High fiber in a vegetarian diet also plays a role in reducing risks of type 2 diabetes and lowering cholesterol levels. (See A Closer Look 10.2—Eat Broccoli for Cancer Prevention.) A further benefit of high-fiber diets is in weight control; the filling effect of fiber suppresses overeating.

Vegetarians, especially vegans, must be knowledgeable about all the nutritional requirements and use care in selecting plant sources that meet those requirements. Special attention must be given to ensure that iron, the B vitamins (especially B12), calcium, vitamin D, and the essential amino acids are supplied. Complementing the essential amino acids is of prime importance because all plant proteins are incomplete. This can be easily accomplished by eating legumes and grains that, in combination, provide an excellent source of protein for the diet. In fact, one study indicates that proteins from plant foods may be preferable to animal protein because consumption of excessive animal protein itself, not just animal fat, may be linked to heart disease and cancer. The suggestion is that meat should no longer be the centerpiece of a meal but instead relegated to a side dish for a vegetarian entrée. Perhaps vegetarians have the right idea.

**CHAPTER SUMMARY**

1. The nutritional needs of the human diet can be categorized into the macronutrients (carbohydrates, proteins, lipids) and micronutrients (vitamins and minerals).
2. Carbohydrates include simple sugars, such as the monosaccharides fructose and glucose and the disaccharides sucrose and lactose. Complex carbohydrates or polysaccharides include starch and glycogen and fulfill the role as the body’s fuel. Dietary fiber includes both soluble and insoluble forms that provide beneficial health effects acting as roughage, promoting regularity, and lowering blood cholesterol levels.
3. All plant proteins are incomplete, deficient in one or more essential amino acids. But complementing incomplete plant proteins such as combining legumes and cereals in a single meal can overcome this deficiency.
4. Lipids include fats and oils, and most of the dietary lipids are classified as triglycerides. A diet high in saturated fats raises the risk of cardiovascular disease. Unsaturated fats, whether monounsaturated or polyunsaturated, lower the risk of cardiovascular disease by lowering LDL cholesterol levels. Foods of animal origin generally are high in saturated fats and cholesterol, but food of plant origin lacks cholesterol and contains mainly unsaturated fats.
5. Deficiency diseases result if a diet lacks any of the essential vitamins and minerals. Fat-soluble vitamins (A, D, E, and K) can be stored by the body but can build up to toxic levels if excessive amounts are taken. Water-soluble vitamins (C and B complex) cannot be stored in appreciable quantities by the body. Most vitamins and minerals (the exception is vitamin B12) can be found in foods of plant origin. The category of minerals (major or trace) is defined by the quantity needed in the body.
6. Americans should modify their diet for a healthier lifestyle. Some fats, like monounsaturated and polyunsaturated fats, are heart-healthy and should become a regular part of the diet. Saturated fats, however, should be limited and trans fats avoided completely. Limit the consumption of white bread, white rice, white potato, and other high
glycemic index carbohydrates to reduce the risk of type 2 diabetes. Limit dairy products that are high in kilocalories and saturated fat. Eat plenty of nonstarchy fruits and vegetables, and take a daily vitamin and mineral supplement. The most important factor for a healthier life is to keep weight under control by limiting total caloric consumption and exercising regularly.

REVIEW QUESTIONS

1. If fiber is largely indigestible, why is it required for a healthy diet?
2. What are the essential amino acids? Why is it important that they be consumed?
3. What is the role of lipids in the body? What is the dietary significance of saturated and unsaturated fats?
4. Describe the following deficiency diseases: scurvy, rickets, marasmus, beriberi, osteoporosis.
5. How closely do you follow the recommended dietary guidelines? Evaluate your diet in terms of a healthy lifestyle.
6. What are the dietary causes of anemia?
7. What differentiates simple carbohydrates from complex carbohydrates?
8. What dietary factors influence the development of cardiovascular diseases or cancer?
9. Estimate the amount of protein you consume in a typical day. What portion is from animal food sources, and what portion is from plant foods?
10. Your friend insists that a vegetarian diet is unhealthy because proteins found in plants are never complete. How would you respond?
11. Concerned about your risk of cardiovascular disease, you undergo a blood test for cholesterol at a health fair at the local supermarket. The test results indicate your total cholesterol count is 190. Is further testing necessary?

FURTHER READING


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